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PROGRESS REPORT
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ENVIRONMENTAL PROGRAMS

November 1, 1976 - April 30, 1977

WHITE RIVER SHALE PROJECT
Federal Prototype Oil Shale Leases
Ua and Ub

August 1977

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FEDERAL PROTOTYPE OIL SHALE LEASES Ua AND Ub

August 1977

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Section 1.0

SUMMARY

This "Progress Report -- Lease Suspension Period Environmental Programs" addresses the work accomplished during the first six months of the original one year suspension of lease terms' period. During this period White River Shale Project continued work on water, air and biological monitoring activities. In addition, work was continuing on revegetation research, and preparation of the final report concerning the two-year Environmental Baseline Program.

Some changes were made in the program from that presented in the "Work Plan" published in December of 1976. Freezing conditions in the White River prevented using the automatic sediment sampler from mid December to the end of April. Manual collection of sediment samples was used instead. Lack of snow cover prevented conducting the large mammal survey. An additional flushing transect survey was carried out in April since the relatively mild winter was expected to accelerate biological activity on the tracts earlier than originally expected. Other alterations to the Work Plan were made as necessary and are discussed in the report.

Ozone and non-methane hydrocarbon levels remained at measurable levels during the reporting period. Non-methane levels exceeded the values listed in the National Ambient Air Quality Standards in 7% of 6-9:00 am periods monitored. Though measured ozone levels did not exceed the standards' value of 160 $\mu g/m^3$, the two highest readings were 130 $\mu g/m^3$ and 120 $\mu g/m^3$.

Plans for the remainder of the original lease suspension period call for continuing present monitoring efforts, publishing the final report on the two-year Environmental Baseline Monitoring Program, and proceeding with ongoing revegetation research.

The final report covering the full 12 month suspension period will be published by May 1, 1978.

Section 2.0

INTRODUCTION

The White River Shale Project (WRSP) was formed in 1974 to operate the joint venture development of the two Federal Prototype Oil Shale Lease Tracts (Ua/Ub) in Utah. WRSP is responsible to Sunoco Energy Development Company, Sohio Petroleum Company and Phillips Petroleum Company for carrying out the planning and implementation of development activities.

Two significant tasks have been completed by WRSP since work under the leases began. First, the Detailed Development Plan required by the leases was submitted to the U. S. Geological Survey - Area Oil Shale Supervisor (AOSS) in June of 1976. This plan describes the activities, timing and results expected for development of Tract Ua/Ub into a 100,000 barrel per day oil shale processing facility. Second, the required two-year Environmental Baseline Program was completed in January of 1977.

Operations under the Ua/Ub leases, however, were suspended for one year effective November 1, 1976. This effectively postponed the implementation of the program described in the Detailed Development Plan (DDP). The lease terms were suspended because the Environmental Baseline Program detected levels of airborne ozone and non-methane hydrocarbons which exceeded Federal National Ambient Air Quality Standards. This situation precludes proceeding with development as described in the DDP until the regulations are modified or provisions are made for allowing construction of facilities in areas which do not meet air quality standards under natural conditions.

In December of 1976 the "Work Plan -- Lease Suspension Period Environmental Programs" was submitted to the Area Oil Shale Supervisor (AOSS). This plan presented a program for activities to be carried out during the suspension period. It covered the plans for: 1) completing and reporting the results of the two-year Baseline Program, 2) conducting an Interim Environmental Monitoring Program (subsequently approved by AOSS), 3) continued revegetation research, and 4) reporting on the suspension period progress and results.

The Work Plan calls for a Progress Report to be prepared covering the period November 1, 1976 through April 30, 1977. As noted on page 6-1 of the Work Plan, the major objectives of this report are to transmit data and to discuss the status of the respective programs.

This Progress Report reviews work objectives and methodologies. Changes required from the Work Plan in any area are discussed. The status and future work plans of the programs are presented.

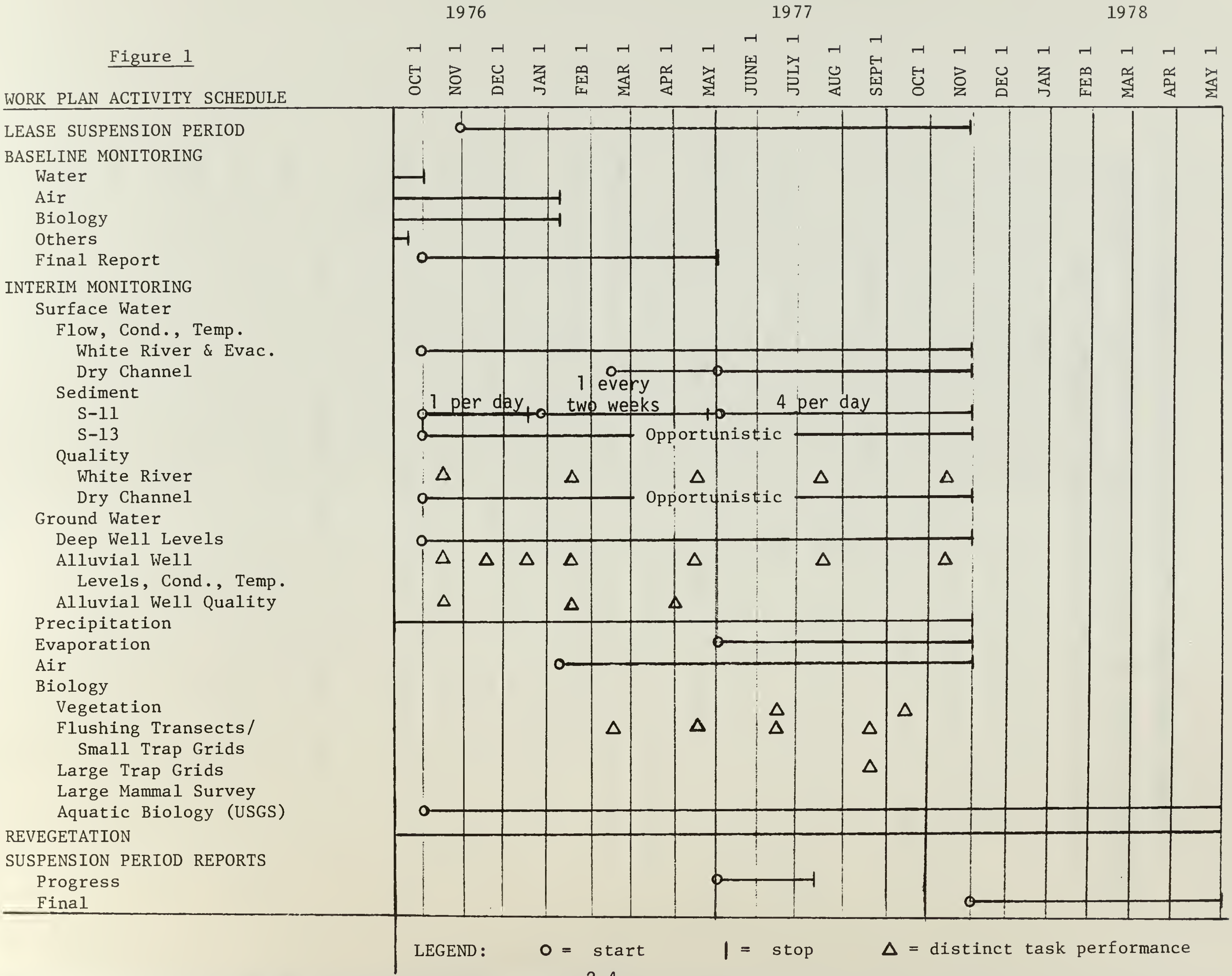
All applicable data available at the time of finalizing this report have been submitted to the AOSS in field package form. The data in this package have been briefly summarized and compared to applicable Baseline Program data in the Progress Report. No detailed data analyses or comparisons have been made.

On June 8, 1977 the Utah Federal District Court granted a preliminary injunction to WRSP against the Department of Interior concerning the stipulations of the leases. The order of preliminary injunction was signed July 1, 1977 and was made effective May 31, 1977. For the purposes of this report it has been assumed that the work envisioned by the December 1976 Work Plan will be conducted as planned at least through November 1, 1977.

Figure 1 shows the current Work Plan Activity Schedule. There are differences between the schedule and the one published in the Work Plan. These changes are discussed in the respective program sections.

Figure 1

WORK PLAN ACTIVITY SCHEDULE



Section 3.0

BASELINE ENVIRONMENTAL MONITORING PROGRAM

The field work for the required two-year Environmental Baseline Monitoring Program was completed January 15, 1977.

Work in regard to the Baseline Program was shifted at that time to data review and report preparation. Evaluation of the Baseline data will continue even after submission in August 1977 of the Final Baseline Report.

3.1 DATA ANALYSIS AND REPORTS

The last Quarterly Baseline Report (#9) for the Baseline Program was submitted to the AOSS in January 1977.

The Final Environmental Baseline Report is expected to be submitted to the AOSS by August 31, 1977. All data not previously presented in Quarterly Baseline Reports will accompany the Final Report.

3.2 ONGOING DATA REVIEW

Conclusions drawn from the Final Baseline Report will be compared to Detailed Development Plan discussions following submission of the Final Baseline Report. Modifications, if any, will be made to the approved Detailed Development Plan as required.

The ongoing data review will also provide a basis for evaluating the results of the Interim Environmental Monitoring Program (see Section 4.0). Modifications will be made in this program if the review suggests that different approaches would provide better methods for meeting the objectives of the monitoring effort.

It is expected that the ongoing data review process will involve more groups than just WRSP. The results of these "outside" reviews should be very valuable in regard to evaluating modifications to the Detailed Development Plan and/or future environmental monitoring programs.

Section 4.0

INTERIM ENVIRONMENTAL MONITORING PROGRAM PROGRESS

The two-year Environmental Baseline Program was completed in total in January 1977. This section will discuss the Interim Monitoring Program which was implemented after completion of the Baseline Program under the terms of the "Notice of Suspension of Operations under the Lease Terms."

The Interim Monitoring Program's primary purpose is to ensure the continuity of data gathering so as to maintain the applicability of the two-year Baseline survey to future monitoring periods. The program discussed in this section, therefore, was planned to fill the "interim" period between completion of the Baseline survey work and the implementation of the monitoring program to be conducted during oil shale development activities.

An additional purpose of the Interim Monitoring Program is to develop more data in areas of specific concern. One of these areas, for example, deals with the levels of the air quality parameters ozone and non-methane hydrocarbons. Levels of these materials were found to exceed National Ambient Air Quality Standards during Baseline monitoring.

Three aspects of the environment are being monitored during the suspension period. These are air, water and biological resources. Figure 1 summarizes the schedule of monitoring activities.

The following sections discuss the work done during the period November 1, 1976 - April 30, 1977.

4.1 WATER RESOURCES

The two year water resources Environmental Baseline Monitoring Program was completed October 1, 1976. An "interim" monitoring program was approved by the AOSS in November. That program was in operation until the program presented in the December 1976 Work Plan was approved for the lease suspension period.

The United States Geological Survey (USGS) is conducting a water resources data collection program in the Uintah Basin drainage area. Much of this data collection is taking place in the immediate vicinity of Tract Ua/Ub. The WRSP Water Resources Interim Monitoring Program was designed to be used in conjunction with pertinent portions of the proposed USGS program. Taken together, the two data collection programs adequately monitor streamflow, suspended sediment, and water quality at locations on the White River, Evacuation Creek and at the mouths of Southam Canyon, Asphalt Wash and Hell's Hole Canyon.

Alluvial aquifers are monitored for water levels and quality at locations upstream and downstream of the tract on the White River and on Evacuation Creek and at locations at the mouths of Southam Canyon and Asphalt Wash. Precipitation and evaporation are monitored at the proposed plant site, in Southam Canyon, and the surrounding area.

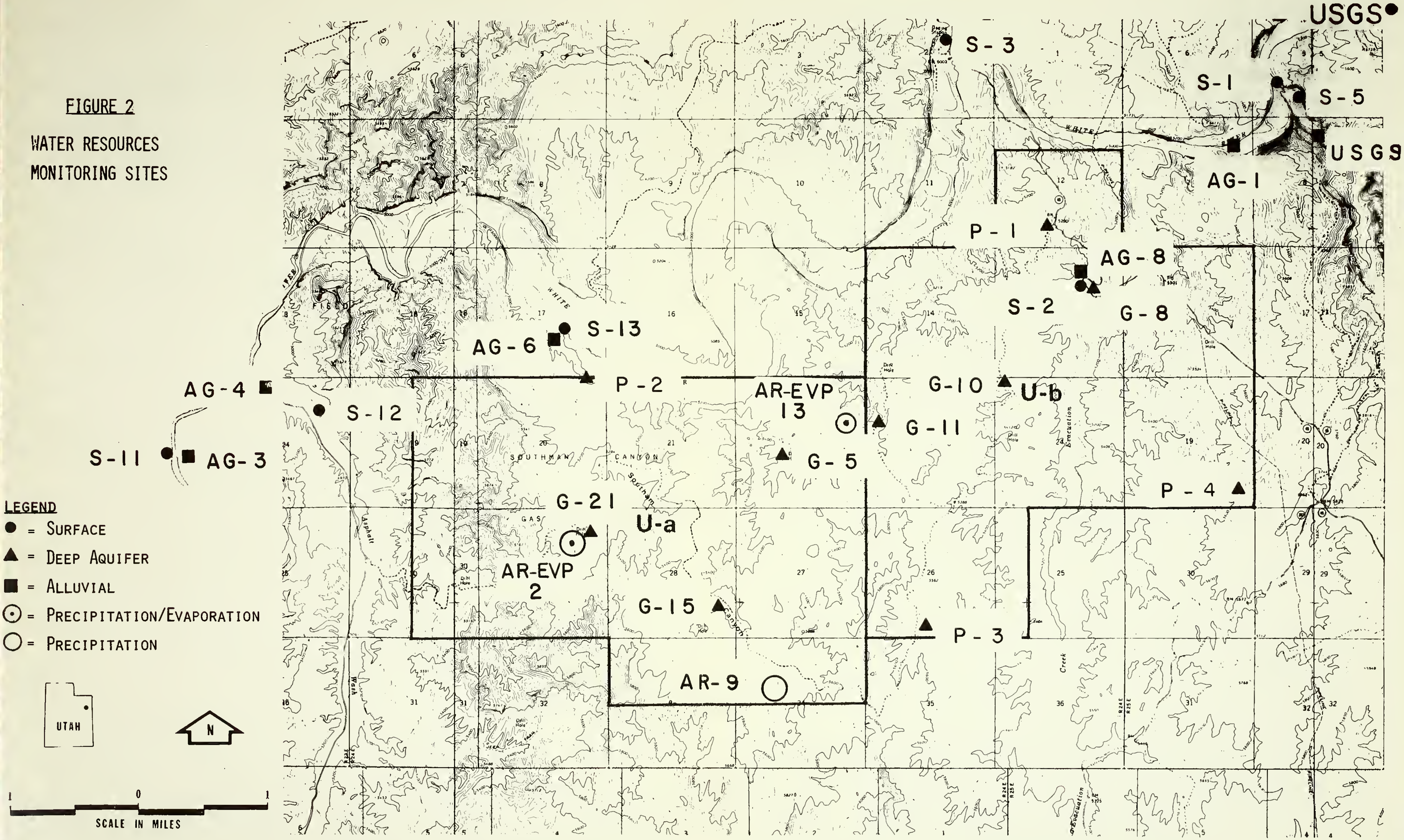
The Birds Nest and Douglas Creek bedrock aquifers are continuously monitored for water level fluctuations. Additional semiannual water level measurements are being taken for area correlation.

Figure 2 shows the locations of monitoring sites for the four types of monitoring being conducted -- surface water, deep aquifer water, alluvial water and precipitation/evaporation monitoring.

VTN Engineers, Inc. is under contract to WRSP for the completion of the water resources element.

FIGURE 2

WATER RESOURCES MONITORING SITES



4.1.1 Surface Water

The surface water monitoring program comprises work efforts of both the USGS Water Resources Division and WRSP. The division of responsibilities is shown in Table 1.

4.1.1.1 Objectives. The objectives of the surface water monitoring program are to ensure the applicability of the two-year Baseline data to future monitoring periods and to correlate data collected from the two-year Baseline White River sites with data from the recently installed USGS station (09306395) upstream of Tract Ua/Ub.

4.1.1.2 Methods. Data collection methods during the reporting period were concerned with streamflow, sediment and water quality data.

Streamflow was measured continuously by the WRSP on the White River downstream from the tract (S-11). The gauging station visitation and maintenance program were sufficient to ensure as near continuous stream-stage measurement throughout the lease suspension period as practical. The station was calibrated using current meter measurements as frequently as called for by good hydrological practices, but no less frequently than once per month.

Streamflow was monitored at an existing station, S-1, on the White River above the tract for 30 days during low flow in order to provide information for verifying correlation between S-1 and the new USGS upstream White River Station called "Stateline" (USGS - #09306395). The digital recorder tapes were removed and processed monthly.

Table 1

RESPONSIBILITY FOR SURFACE WATER MONITORING

ACTIVITY	RESPONSIBILITY
Flow	
- S-11 continuous	VTN
- S-1 30-day high-flow and low-flow for Stateline correlation	VTN
- S-13, Feb.-Oct.	VTN
- Stateline	USGS
- S-3	USGS
- S-2	USGS
- S-12 and S-5 Apr.-Oct.	USGS
Suspended Sediment	
- S-11 continuous (high-flow, 4 samples daily, Feb.-Oct., and 1 sample daily Nov.-Jan.)	VTN
- S-13 opportunistic	VTN
- S-2 and Stateline auto samplers - monthly	USGS
- S-5 and S-12 2-bottle single stage - opportunistic	USGS
Water Quality	
- S-11 quarterly Jan., Apr., July, Oct.	VTN
- S-13 opportunistic	VTN
- S-11 and S-13 continuous SC and Temp.	VTN
- S-1 Temp. and SC for 1 month low and 1 month high for ≥0.9 Correl. Coeff.	VTN
- S-2, S-3, Stateline quarterly samples	USGS

Streamflow was also measured by WRSP in lower Southam Canyon (S-13). According to plan, this station was started up on February 17, 1977, after the winter shutdown. It is to be operated through October. The station was visited, during the period of operation, at least once each month. The digital recorder tapes were removed and processed once a month.

Streamflow data was monitored continuously by the USGS at a new Station called Stateline, located 1 mile upstream from S-1 on the White River, at S-3 on the White River near Ignatio, at S-2 on Evacuation Creek near the mouth, and on Evacuation Creek near Dragon. S-12 on Asphalt Wash near the mouth and S-5 in Hell's Hole Canyon near the mouth were put into operation on February 10, 1977 and February 7, 1977 respectively after the winter shutdown.

Suspended sediments were measured by the WRSP at S-11 and S-13. At S-11 the automatic suspended sediment sampler was to be operated continuously according to the Work Plan. Severe icing conditions, however, required that it be shut down from December 16, 1976 to March 25, 1977. During the shutdown manual samples were withdrawn once every two weeks. The automatic sediment sampler was restarted and set to collect four samples a day beginning April 28, 1977. The duration of this sampling period will depend upon the prevailing hydrological conditions and the judgment of the resident senior WRSP hydrographer. Manual ETR suspended sediment measurements were performed at intervals necessary to ensure calibration of the automatic sampler, but at least monthly through the 6-month period. Because of the lack of major snowmelt runoff, no sampling beyond the normal schedule was done.

No suspended sediment samples were collected at S-13 since no flow occurred at that site. A single-stage sampler and a crest gauge were maintained at that location to enhance the chances for data collection.

Sediment samples were analyzed by the WRSP, and daily values of streamflow and suspended sediment were calculated.

An automatic sediment sampler was used by the USGS at Stateline (#09306395) and S-2 stations, and two-bottle single-stage samplers were in use at the S-5 and S-12 locations. Suspended sediment data was collected at S-2 and Stateline, but no samples could be collected at S-5 and S-12 since there was no flow.

Water quality samples were collected by WRSP at S-11. Samples at S-11 were collected October 21, 1976, January 4, 1977, and April 27, 1977. No water quality samples were collected from S-13 since no flow occurred. Dissolved oxygen, temperature, pH and conductivity were measured in the field at the time samples were collected. The constituents were analyzed in accordance with the quarterly and semiannual analytical schedule shown in Table 2.

Temperature and conductivity were measured continuously at S-11. Both probes were checked and calibrated regularly, and the digital recorder tapes were pulled and processed monthly. Temperature and conductivity probes were maintained at S-13 during the period of its operation. At S-1, streamflow, temperature and conductivity were monitored continuously until November 26, 1976 to verify correlation with "Stateline". Another period of concurrent operation began April 25, 1977 continuing to June 9, 1977, the high flow period in 1977. Correlation coefficients will be calculated among Stateline, S-1 and S-3 records

Table 2

OIL SHALE PROJECT - WATER QUALITY

SURFACE WATER SCHEDULE - USGS (REVISED DECEMBER 3, 1975

Samples will be collected and analyzed according to the following schedule:

Quarterly (October, January, April, July)

Calcium
Magnesium
Sodium
Potassium
Chloride
Sulfate
Bicarbonate
Carbonate
Alkalinity
Hardness

Fluoride
Silica
Iron
Aluminum
Boron
Lithium
Strontium
Manganese
Phosphate
Total Phosphorus

Nitrate
Nitrite
Ammonia
Total Kjeldahl Nitrogen
Chemical Oxygen Demand
Chlorophyll A
Chlorophyll B
Color
Turbidity
Dissolved Solids

Semiannually (October, Apirl)

Arsenic
Cadmium
Chromium
Copper
Mercury
Molybdenum

Selenium
Vanadium
Zinc
Barium
Sulfide
Bromide

Lead
*Detergents
Organic Carbon (Dissolved)
*Pesticides
Phenols
**Gross Alpha & Beta

Whenever a station is visited, field measurements will be made of pH, temperature, conductivity and dissolved oxygen.

* Not included in WRSP Program.

** If gross alpha activity is measured at greater than 4 picocuries/liter, then analysis for radium 226 and for natural uranium will be done. If gross beta activity is greater than 100 picocuries/liter, then analysis for Sr^{90} and Ce^{137} will be done.

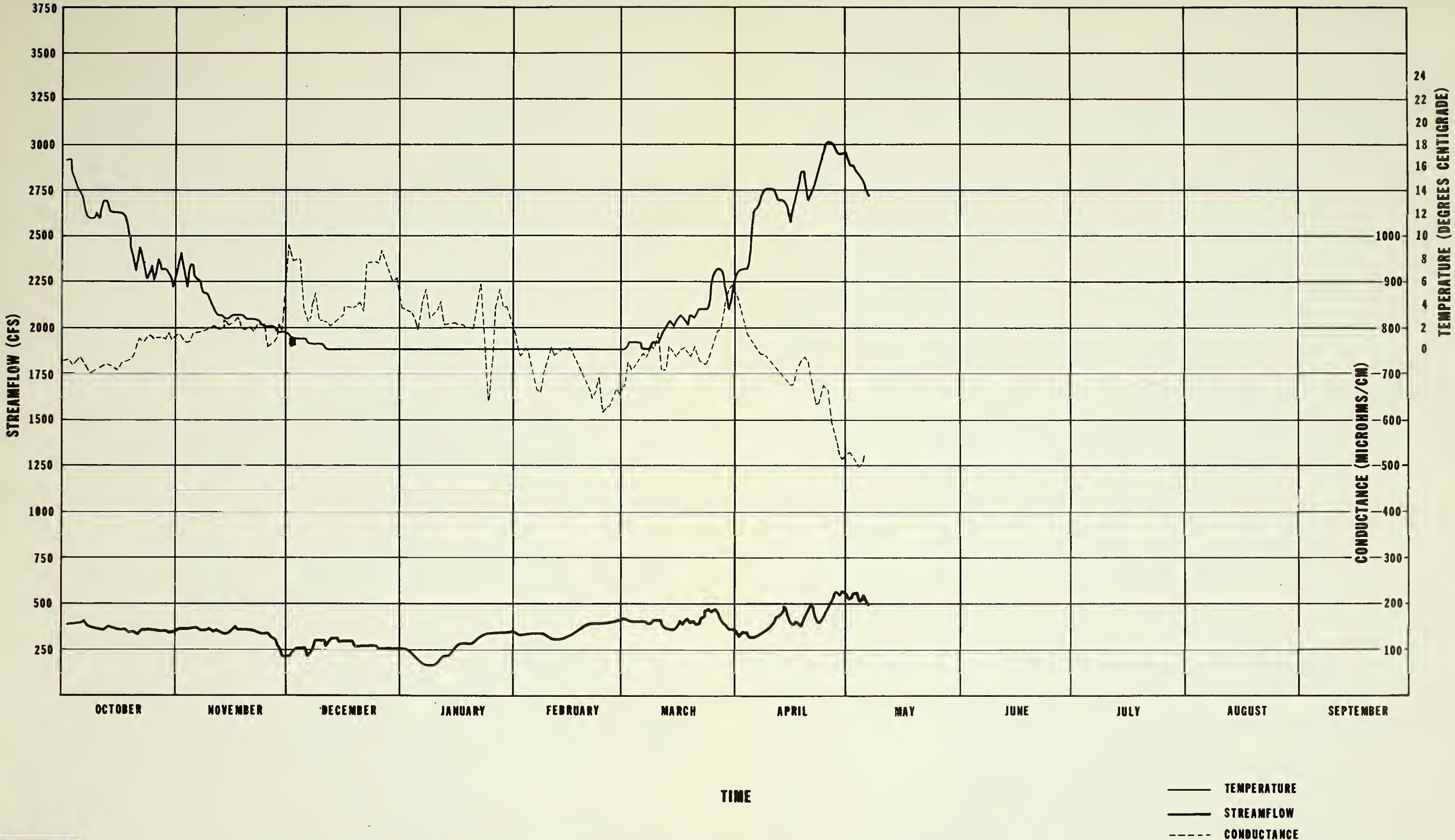
within 30 days following receipt of final USGS data for S-3 and Stateline. Operation of S-1 will be permanently discontinued if the correlation coefficient between the S-1 and Stateline records from both periods is ≥0.9, and if the standard error of estimate is ≤10% based on daily values. If this criteria is not met, then the S-3 records will be used to determine whether the records contain erroneous data which may bias the analysis.

Recorder tapes were pulled and processed monthly.

Water quality samples were collected by the USGS and analyzed quarterly at S-2, S-3 and Stateline. The samples were analyzed for the constituents listed in Table 2. (This list is currently being revised by the USGS.)

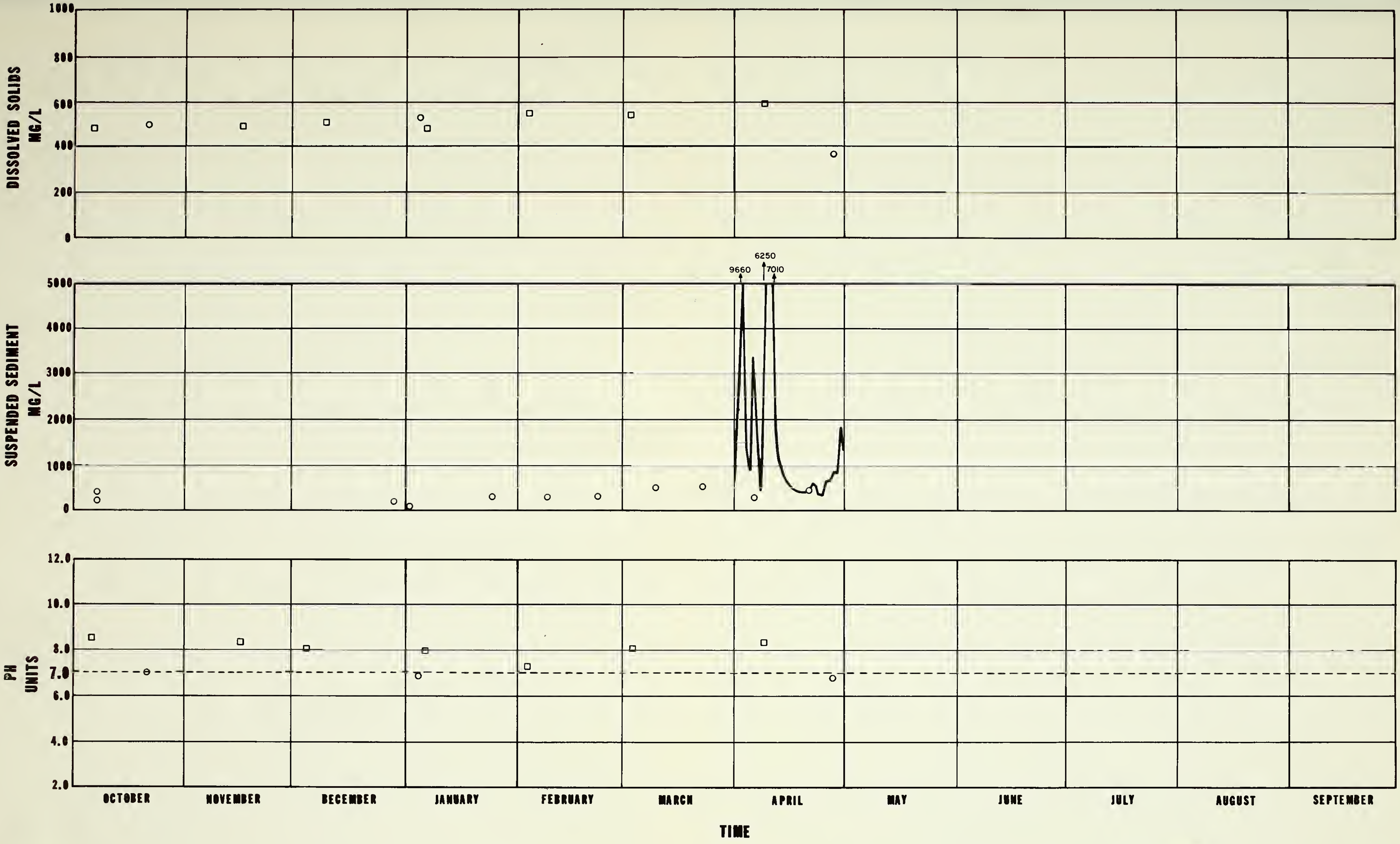
4.1.1.3 Results to Date. During the interim period, streamflow, temperature, and conductance have followed the same patterns established during the Baseline study, as seen in Figure 3. Baseflow occurred from October through February, as expected. Lower basin and upper basin runoff began earlier than expected--in December and mid April, respectively--and in considerably reduced volumes. Temperature followed the annual sinusoidal pattern, and specific conductance followed the inverse relationship to streamflow established during the Baseline study.

Water quality also followed the patterns established during the Baseline study, as seen in Figures 4 through 8. Sodium and sulfate concentrations increased between December and March, as expected, reflecting the increased proportion from lower basin runoff. Macronutrient concentrations followed the established pattern: Nitrate and



MEAN DAILY TEMPERATURE, STEAMFLOW AND SPECIFIC CONDUCTANCE
WHITE RIVER NEAR WATSON UTAH - (S-3)
OCTOBER 1976 - MAY 1977

FIGURE 3



LEGEND

- ● WHITE RIVER AT STATE LINE
- ☐ WHITE RIVER NEAR WATSON (S-3)
- ○ WHITE RIVER BELOW ASPHALT WASH (S-11)
- — DAILY AUTOMATIC SEDIMENT SAMPLING

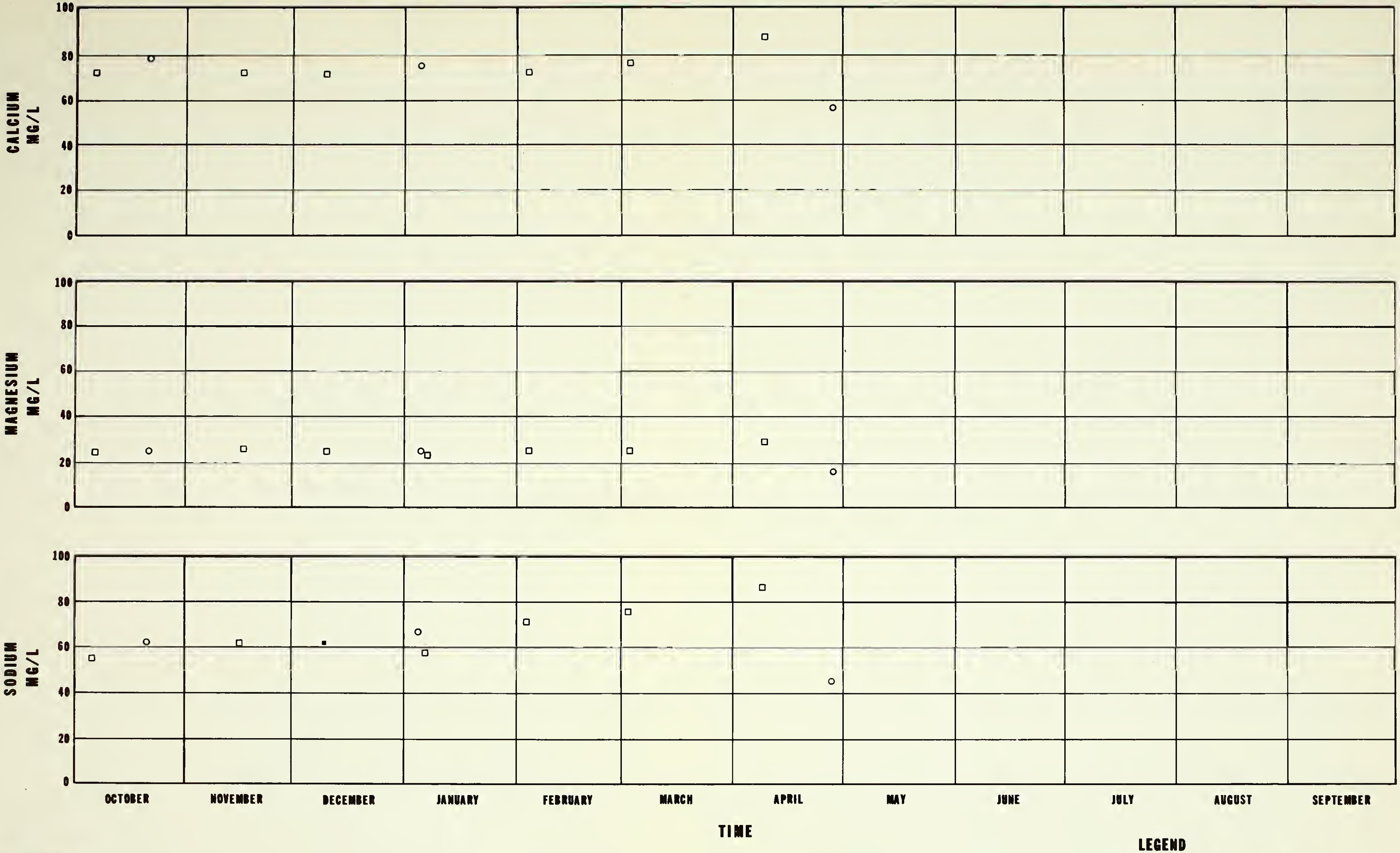
vtn

VARIATION OF GENERAL CHARACTERISTICS

WHITE RIVER FROM ABOVE HELLS HOLE CANYON TO BELOW ASPHALT WASH

OCTOBER 1976 - SEPTEMBER 1977

FIGURE 4



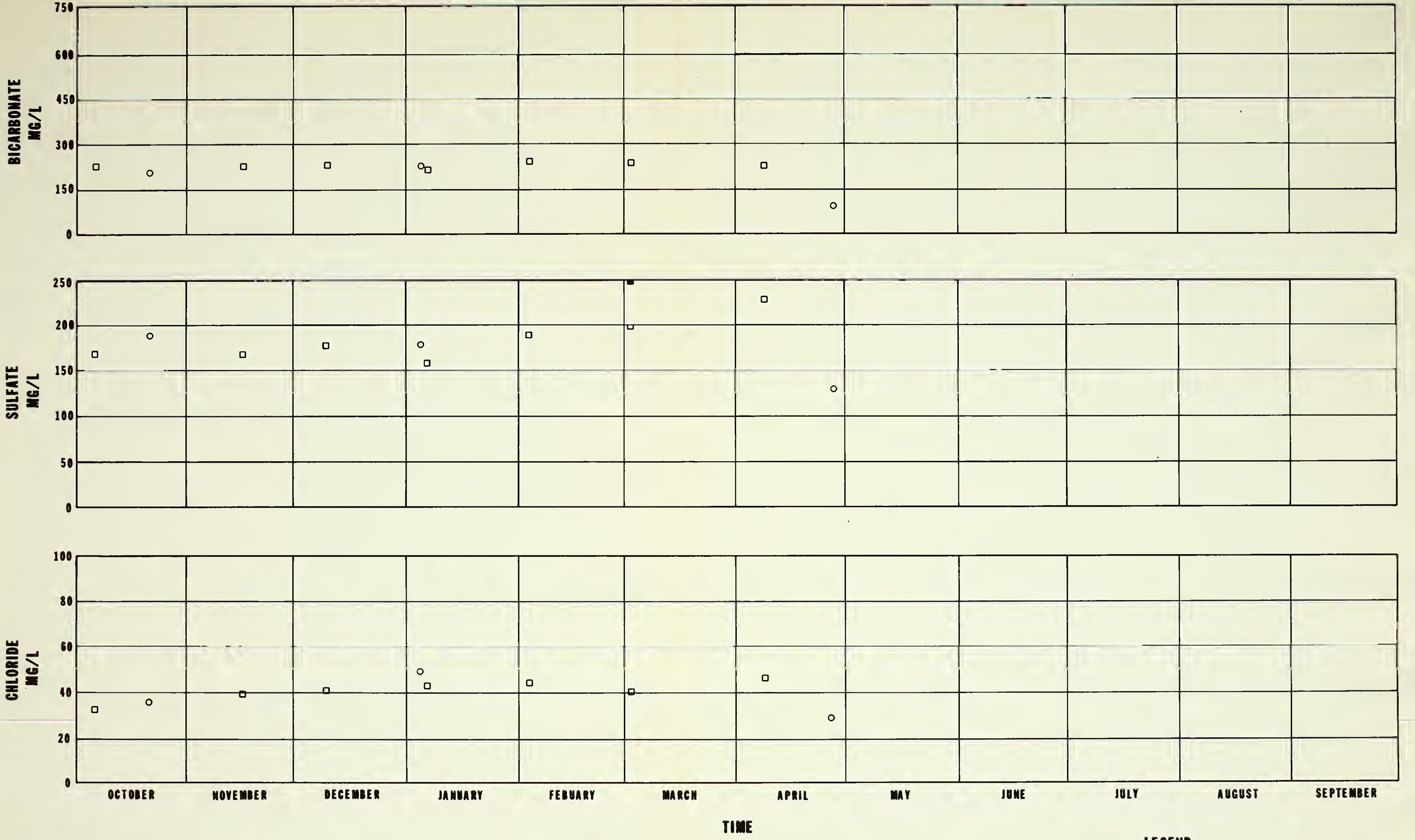
LEGEND

- ● WHITE RIVER AT STATE LINE
- □ WHITE RIVER NEAR WATSON (S-3)
- ○ WHITE RIVER BELOW ASPHALT WASH (S-11)

VARIATION IN TIME OF MAJOR CATIONS

WHITE RIVER FROM ABOVE HELLS HOLE CANYON TO BELOW ASPALT WASH
OCTOBER 1976 - SEPTEMBER 1977

FIGURE 5



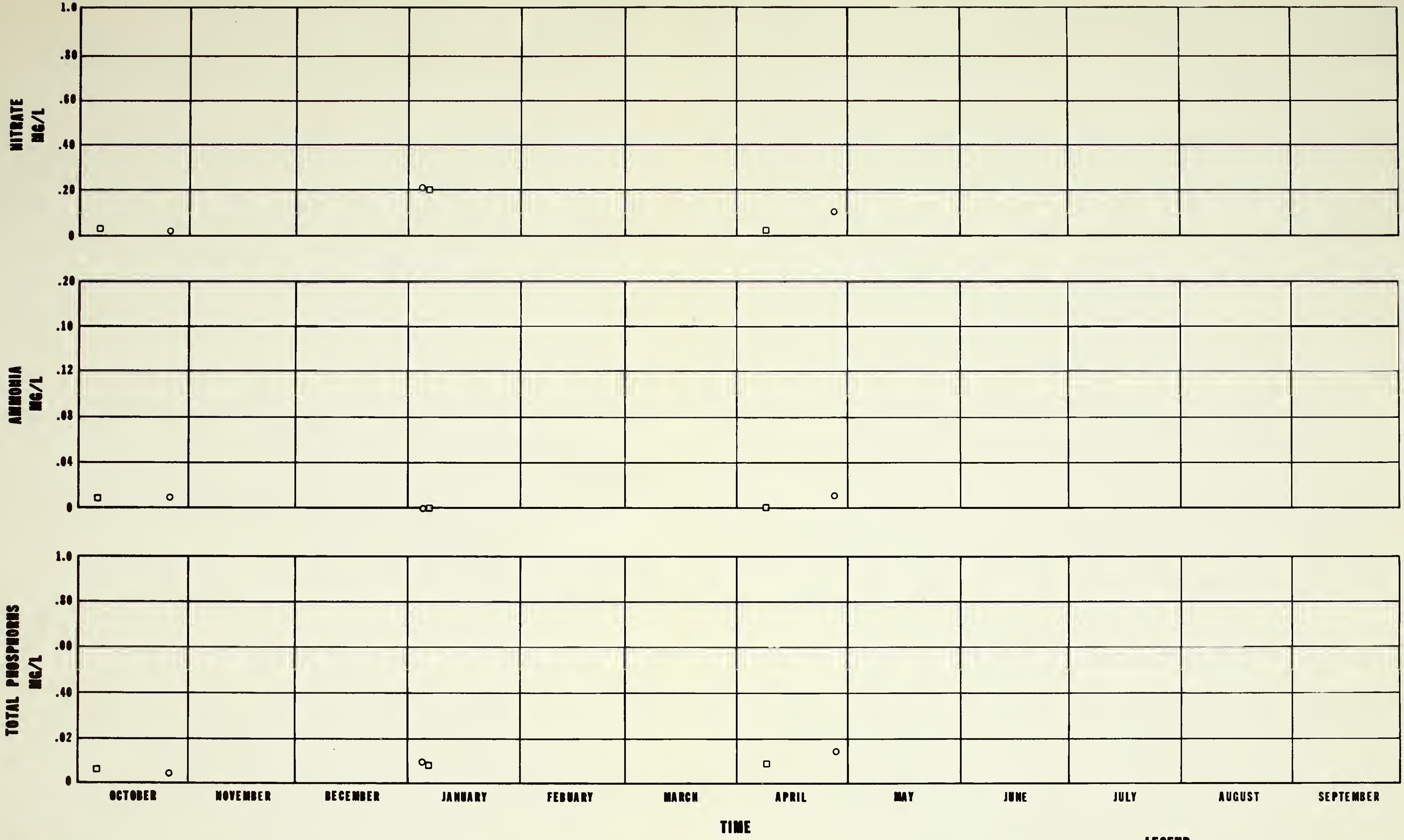
LEGEND

- ● WHITE RIVER AT STATE LINE
- ☐ WHITE RIVER NEAR WATSON (S-3)
- ○ WHITE RIVER BELOW ASPHALT WASH (S-11)

VARIATION IN TIME OF MAJOR ANIONS

WHITE RIVER FROM ABOVE HELLS HOLE CANYON TO BELOW ASPHALT WASH
OCTOBER 1976 - SEPTEMBER 1977

FIGURE 6



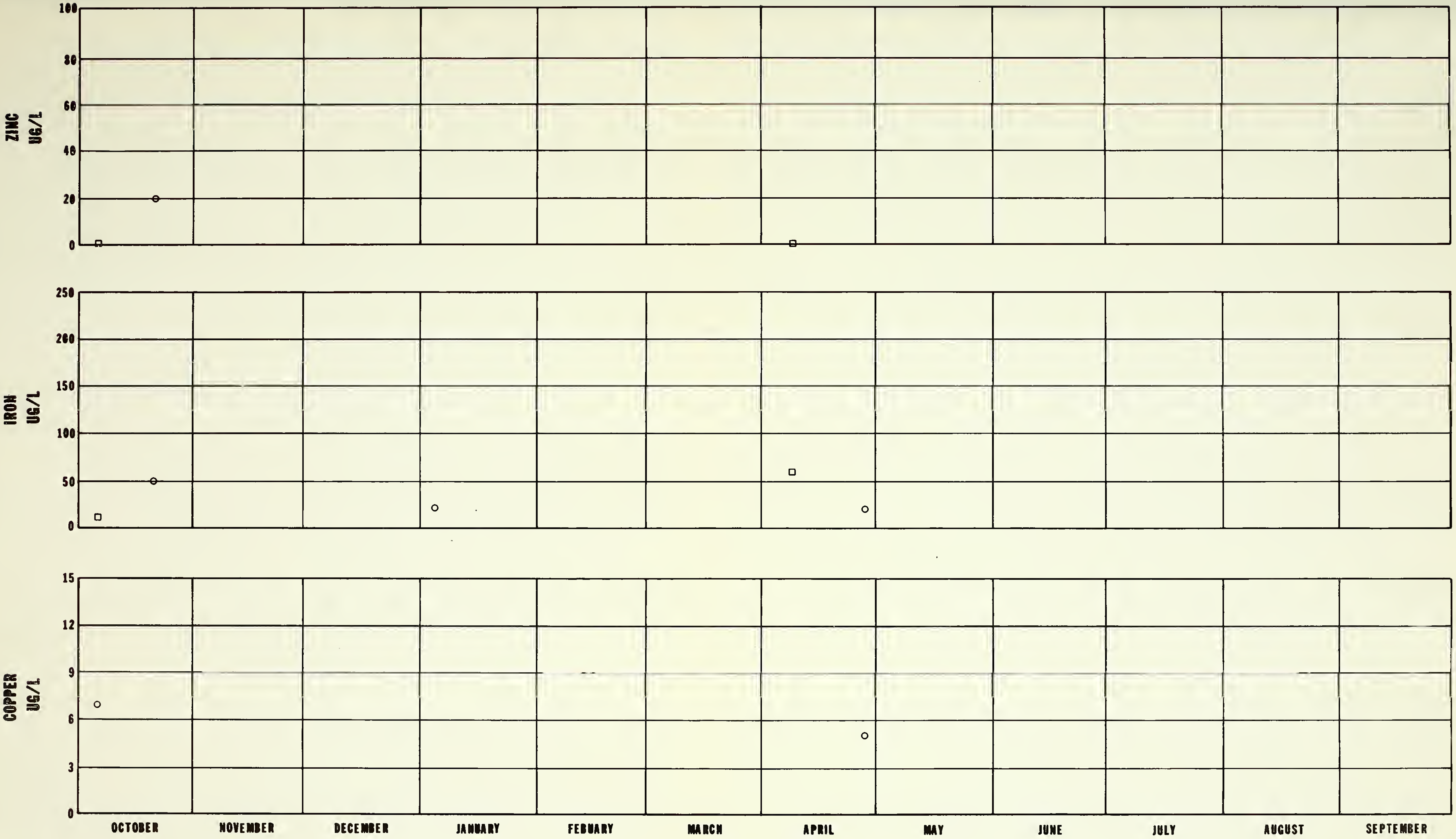
LEGEND

- ● WHITE RIVER AT STATE LINE
- ☐ WHITE RIVER NEAR WATSON (S-3)
- ○ WHITE RIVER BELOW ASPHALT WASH (S-11)

VARIATION IN TIME OF REPESENTATIVE MACRONUTRIENTS

WHITE RIVER FROM ABOVE HELLS HOLE CANYON TO BELOW ASPHALT WASH
OCTOBER 1976 - SEPTEMBER 1977

FIGURE 7



LEGEND

● WHITE RIVER AT STATE LINE
□ WHITE RIVER NEAR WATSON (S-3)
○ WHITE RIVER BELOW ASPHALT WASH (S-11)

VARIATION IN TIME OF SOME MICRONUTRIENTS
WHITE RIVER FROM ABOVE HELLS HOLE CANYON TO BELOW ASPHALT WASH
OCTOBER 1976 - SEPTEMBER 1977

FIGURE 8

ammonia values were high in mid-winter, and phosphorus increased with increasing runoff. Micronutrients showed no clear trends, with levels throughout interim monitoring similar to those during Baseline monitoring.

4.1.2 Deep Aquifer Water

The aquifer monitoring program, like the surface water program, is based on a combination of WRSP and USGS efforts. Division of responsibilities is shown in Table 3.

4.1.2.1 Objectives. The objectives of this monitoring element are to extend water level data so as to provide continuity between the Baseline work and future monitoring periods, and to investigate long-term water level trends.

4.1.2.2 Methods. Water levels were continuously monitored by the USGS at P-1, P-2 Upper and P-2 Lower, and by the WRSP at P-3. Float and time activated digital punch recorders were recording the level every hour at P-1, P-2 Upper and P-2 Lower, and P-3. For quality assurance, WRSP manually checked the water level at P-3 once per month.

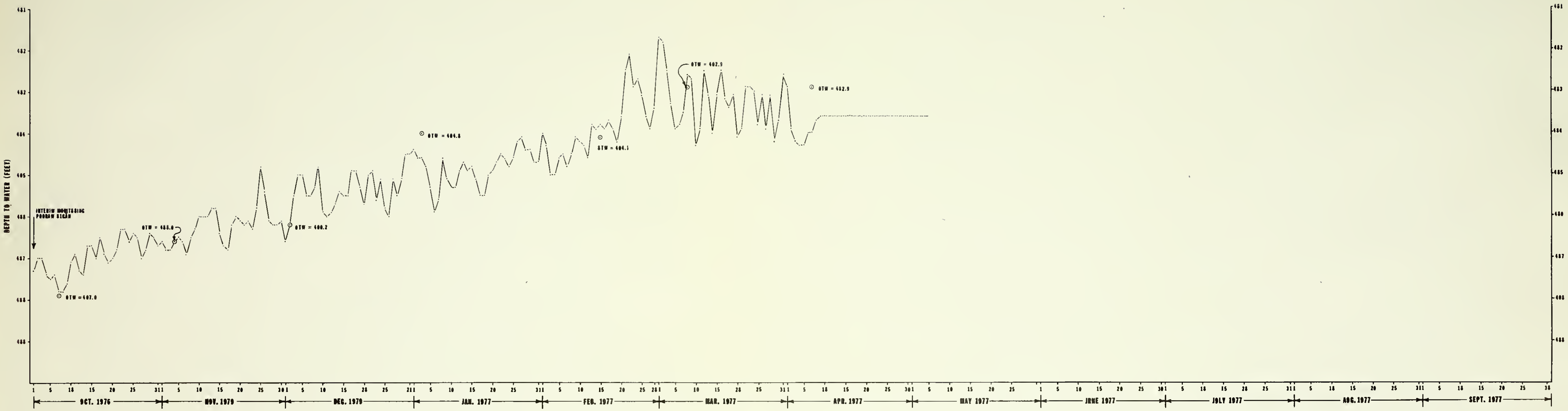
Manual water level readings were taken by WRSP at G-8, G-8A, G-5, G-10, G-11, G-15, G-21 and P-4 in January 1977, which corresponded to the period of minimum water levels as found during the Baseline period. A water level reading will be taken during the most likely high level period as well.

4.1.2.3 Results to Date. The continuous hydrographs for Well P-3 are shown in Figure 9; hydrographs for Wells P-1, P-2U, and P-2L

Table 3

RESPONSIBILITY FOR GROUND WATER MONITORING

ACTIVITY	RESPONSIBILITY
Deep Aquifer	
- P-1, P-2, P-2U, and P-2L continuous	USGS
- P-3	VTN
- G-8, 8A, 5, 10, 11, 15, 21, and P-4 semi-annually	VTN
Alluvial Wells	
- Quarterly quality samples, monthly water-level samples through Dec. 1976	USGS
- AG-2, 3, 4, 5, 7, 8 and 9 monthly water-level, temperature and SC through Jan. 1977	VTN & USGS
- AG-1 and AG-6, quality samples once at high flow and once at low flow, and monthly water-level samples, in Feb.-Oct.	VTN & USGS



CONTINUOUS MONITORING WELL P-3
(SURFACE ELEVATION 5486.0′)

FIGURE 9

are in the field data section, and Table 4 lists the water levels measured January 17, 1977, in the other deep wells. The data show a continuation of trends established during the Baseline program.

4.1.3 Alluvial Water

The USGS Water Resources Division incorporated several WRSP wells into their own program. The program discussed below, therefore, was carried out by the USGS, and represents the program as initiated October 1, 1976, and with modifications effective in January 1977. Table 3 presents the division of responsibilities on this program.

4.1.3.1 Objectives. The objectives of the program are to extend the data base in regard to alluvial well water levels and water quality, and to begin identifying long-term trends of these two parameters.

4.1.3.2 Methods. Monthly water level, temperature and conductivity measurements were made through December 1976 at eight locations in five drainage areas:

1. White River (AG-1 Upper/Lower and AG-3 Upper/Lower)
2. Hell's Hole Canyon (U/L near mouth)
3. Evacuation Creek (AG-8 U/L, near Park Canyon U/L, and above Missouri Creek U/L)
4. Southam Canyon (AG-6 U/L)
5. Asphalt Wash (AG-4 U/L)

Water quality samples were withdrawn quarterly through December 1976 and analyzed pursuant to the schedule in Table 5. Additional water

Table 4

DEEP WELL WATER LEVELS

January 17, 1977

Well	Depth to Water (feet)
G-8	53.20
G-8A	43.60
G-5	460.64
G-10	320.85
G-11	468.18
G-15	510.20
G-21	430.85
P-4	265.69

Table 5

OIL SHALE PROJECT - WATER QUALITY

GROUND WATER SCHEDULE - USGS SITES (REVISED DECEMBER 3, 1975)

Sodium
Aluminum
Arsenic
Boron
Barium
Bromide
Calcium
Cadmium
Chloride
Chromium
Copper
Fluoride
Iron
Mercury
Potassium

Iodide
Lithium
Magnesium
Manganese
Molybdenum
Nitrate & Nitrite
Ammonia
Total Kjeldahl Nitrogen
Phosphate
Total Phosphorus
Lead
Sulfate
Sulfide
Selenium
Silica

Strontium
Vanadium
Zinc
Dissolved Solids
Bicarbonate
Carbonate
Alkalinity
Hardness
Organic Carbon (Dissolved)
*Gross Alpha & Beta
Radium 226
**Temperature
**Conductivity
**pH

---

* If gross alpha activity is measured at greater than 4 picocuries/liter, then analysis for radium 226 and for natural uranium will be done. If gross beta activity is greater than 100 picocuries/liter, then analysis for Sr^{90} and Ce^{137} will be done.

** Field Measurements

quality samples would have been withdrawn from AG-1, AG-3, AG-6 and AG-8 if the conductivity measurement were 20% higher than the maximum recorded value, or 20% lower than the minimum recorded value of record for a coresponding past period.

The program frequency of sampling was modified in January 1977. The locations remained the same. Effective that month, conductivity, temperature and water level were to be measured quarterly. A water quality sample was taken once during the high flow period of 1977 by the USGS at AG-1, AG-3, AG-6 and AG-8. Monthly water level, conductivity and temperature measurements resumed at AG-1 and AG-6 during snowmelt and thunderstorm seasons (approximately February-October).

4.1.3.3 Results to Date. The monitoring stations and the responsibility for the various monitoring activities are listed in Table 3. Water level, temperature, and conductivity values measured so far are listed in Table 6, and water quality data are in the field data section.

4.1.4 Precipitation/Evaporation

The following program was implemented during January 1977. The Interim Monitoring Program was modified from the Baseline program insofar as fewer sites were used.

4.1.4.1 Objectives. The objectives of the precipitation/evaporation program are to augment the USGS regional data collection

Table 6

ALLUVIAL WELL MEASUREMENTS

WELL		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
AG-1 Upper	Date	15	22	29	30	15	30	29					
	Level	13.44	13.65	11.17	10.39	10.96	13.54	13.80					
	Temp.					3.0	7.0	10.2					
	Cond.				1,800	1,420	1,300	1,400					
AG-1 Lower	Date	15	22	29	31	15	30	29					
	Level	13.55	13.54	11.35	10.49	10.95	13.43	12.65					
	Temp.	10.5	10.0	9.5		9.5	9.0	10.2					
	Cond.	1,150	1,125	850	1,050	920	920	1,150					
AG-3 (WRSP)	Date	19	23	27	28	8			5				
	Level	12.36	12.29		11.74	11.43			11.89				
	Temp.	12.5	11.0	9.0	9.0	10.0			9.0				
	Cond.	3,800	3,590	3,300	3,300	3,340			3,300				
AG-3 Upper (USGS)	Date	7	23	27	28	8			5				
	Level	11.71	11.77	11.65	11.26	10.96			11.38				
	Temp.	14.5	12.5	11.0		10.5			10.5				
	Cond.	3,000	2,600	2,400		2,640			2,500				
AG-3 Lower (USGS)	Date	7	23	27	28	8			5				
	Level	12.58	12.66	12.44	12.09	11.76			12.20				
	Temp.	13.5	11.0		11.0	10.5			11.0				
	Cond.	4,600	4,600		4,100	4,300			4,300				
AG-4	Date	19	22	28	28	8			5				
	Level	30.36	30.34	30.28	29.67	29.60			29.95				
	Temp.	12.5	12.5		12.0	12.0			11.0				
	Cond.	2,150	2,100		1,400	1,400			1,370				
AG-6 Upper	Date	12	22	28	28	8	30	29					
	Level	19.00	18.96	18.90	18.44	18.38	18.83	19.2					
	Temp.	13.5	14.0	11.0	11.0	12.0	12.0	15.5					
	Cond.	4,000	3,400	3,280	2,100	3,000	2,300	2,050					
AG-6 Lower	Date	12	22	28	28	8	30	29					
	Level	17.77	17.70	17.68	17.19	17.13	17.57	Dry					
	Temp.	13.5	12.0	12.0	12.0	12.0	12.0						
	Cond.	6,900	5,900	6,480	4,900	6,200	5,600						
AG-8	Date	15		29	31	15			5				
	Level	5.14		Frozen	Frozen	Frozen			4.37				
	Temp.	14.0							9.5				
	Cond.	5,200							4,900				
Hells Hole (Upper)	Date	14	29	29	30	15		7					
	Level	17.46	17.51	17.49	17.60	17.60		17.70					
	Temp.												
	Cond.												
Hells Hole (Lower)	Date	14	29	29	30	15		7					
	Level	16.87	16.90	16.94	17.01	16.99		17.06					
	Temp.												
	Cond.												

network (see Figure 10), provide site specific information on precipitation and evaporation at the plant site and processed shale disposal area, and to place the Interim period in historic perspective.

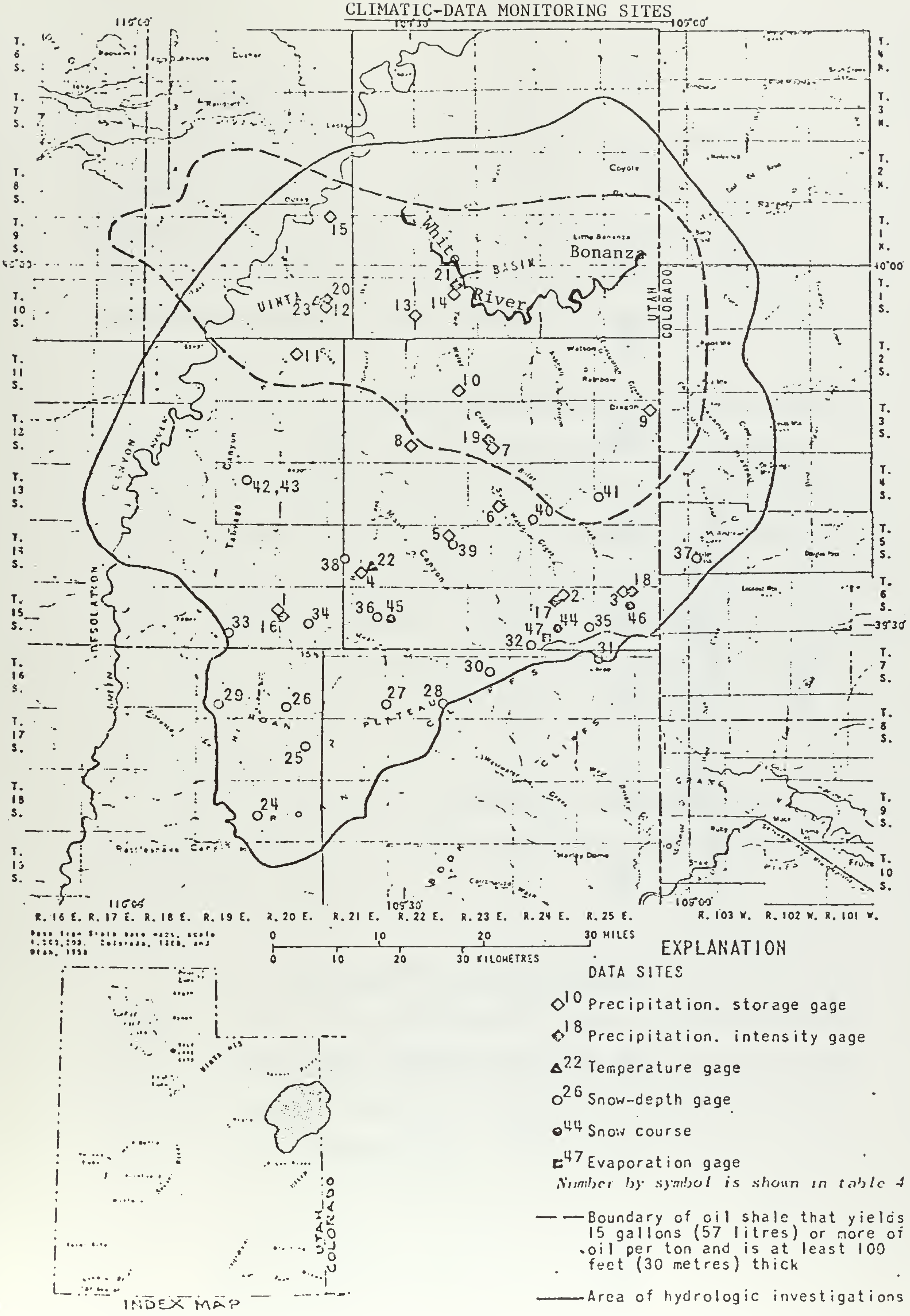
4.1.4.2 Methods. Precipitation was measured by automatic gauges at three locations beginning in April 1977. The plant site gauge (AR-13) and at Southam Canyon site (AR-2) are operated year round. The other Southam Canyon site (AR-9) was put into operation during April and expected to be operated through October 1977.

Evaporation was measured in Southam Canyon (EVP-2) and at the proposed plant site (EVP-13) during the freeze-free period.

4.1.4.3 Results to Date. The data are being collected and reduced by WRSP. USGS data are included as they become available and are pertinent to the report discussion. The results of monitoring are in Table 7.

FIGURE 10

CLIMATIC-DATA MONITORING SITES



Base from State base maps, scale 1:500,000; Colorado, 1969, and Utah, 1950

EXPLANATION

DATA SITES

◇10 Precipitation. storage gage

◈18 Precipitation. intensity gage

▲22 Temperature gage

○26 Snow-depth gage

●44 Snow course

▪47 Evaporation gage

Number by symbol is shown in table 4

— — Boundary of oil shale that yields 15 gallons (57 litres) or more of oil per ton and is at least 100 feet (30 metres) thick

—— Area of hydrologic investigations

Table 7

PRECIPITATION AND EVAPORATION RECORDS
OCTOBER 1976 - APRIL 1977

STATION	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	ANN
RS-1	.21	.00	T										
RP-1	.20	.00	.04										
ARA-2	.1	.0	T	.3	.3	.5	1.2						
RS-6	.26	.00	T										
RS-9	.18	.00	.05										
ARS-9	.2	.0	T				1.4						
RS-12	.10	.00	T										
RS-13	.16	.00	.03										
ARA-13	.1	.0	T	.3	.3	.3	1.3						

4.2 AIR RESOURCES

The two-year Environmental Baseline Monitoring Program in air resources was completed by January 15, 1977. This program was a very exhaustive effort in regard to the air quality and meteorology incidental to Tract Ua/Ub. For one year eight air quality monitoring stations were operated. During 1976 four air quality monitoring stations were operated.

The Interim air resources monitoring program element has been designed to be a systematic step between the Baseline Monitoring Program and the Development Monitoring Program described in the Detailed Development Plan. No significant changes in the Work Plan were implemented during the study period. The Interim Monitoring Program will continue collection of pertinent air quality and meteorological information.

Figure 11 shows the locations of the Interim monitoring sites.

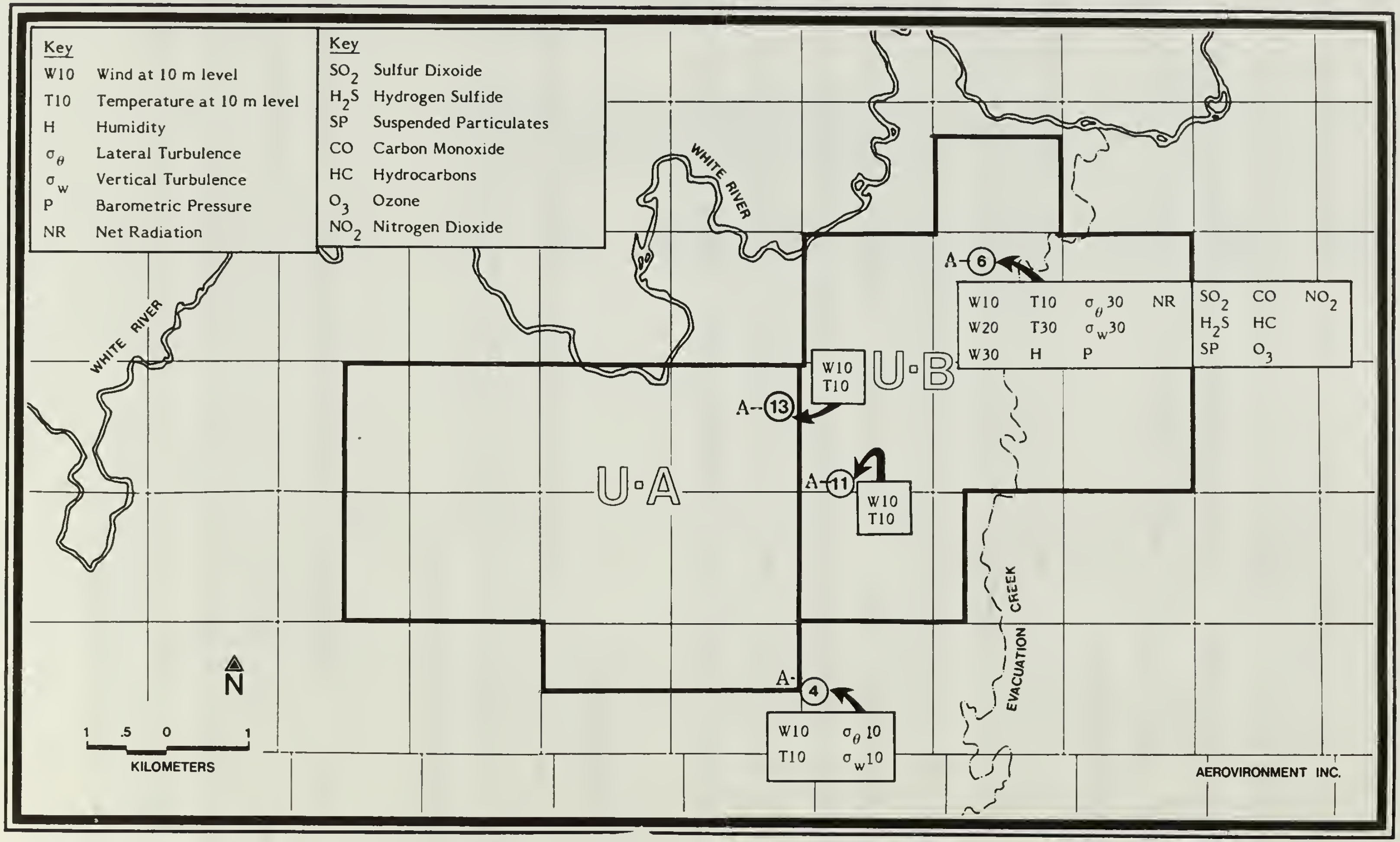
4.2.1 Air Quality

The air quality monitoring program was initiated January 16, 1977. Monitoring equipment and selected locations are identical to those used during Baseline monitoring.

4.2.1.1 Objectives. The prime objective of the program is to determine if the occasional high levels of ozone and non-methane hydrocarbons noted during the Baseline period recur during the Lease Suspension Period. Another objective is to maintain continuity of data on other air quality parameters.

Figure 11

LOCATIONS OF METEOROLOGICAL & AIR QUALITY MEASUREMENT STATIONS ON TRACTS U-a and U-b



4.2.1.2 Methods. Station A-6 (See Figure 11) is operating during the suspension period. Table 8 summarizes the data collected at this location. Table 9 lists the instruments used. All parameters, except suspended particulates, are monitored continuously. Data are recorded on digital punch tapes every 6 minutes, and strip charts every 2 minutes.

Station A-3 is maintained on a standby basis. A-3 has the same instrumentation as A-6 and will be put into service if A-6 becomes inoperable.

Suspended particulates are measured over a 24 hour period at A-6 every sixth day. This schedule is the same as used in the Baseline Monitoring Program and is considered sufficient for continued characterization of the randomly produced background particulate material levels. The specific measurement techniques used are the same as those used during the Baseline program, which have been described extensively in previous reports on that program.

Quality assurance is provided through four techniques. First, all of the instruments used during this year were recalibrated January 11-January 13, 1977. Second, the air quality equipment is recalibrated (dynamic multiple point) monthly and, third, the equipment receives span and zero checks every two days. This schedule of calibration is more frequent than that for the Baseline program. It reflects the greater reliability demanded of single air monitoring station. Fourth, in addition to the normal internal quality assurance procedures maintained by AeroVironment, the White River Shale Project is participating voluntarily in an air pollution measurement quality assurance program implemented by the Environmental Protection Agency.

TABLE 8 Parameters to be monitored during the lease suspension period.

Parameter	Station			
	A4	A6	A11	A13
Air Quality				
Total Sulfur		X		
SO_2		X		
H_2S		X		
Total Hydrocarbons		X		
CH_4		X		
CO		X		
NO		X		
NO_x		X		
NO_2		X		
O_3		X		
Suspended Particulates		X		
Meteorology				
WS/WD - 10 m	X	X	X	X
WS/WD - 20 m		X		
WS/WD - 30 m		X		
T - 10 m	X	X	X	X
T - 10-30 m		X		
σ_θ - 10 m	X			
σ_θ - 30 m		X		
σ_w - 10 m	X			
σ_w - 30 m		X		
Solar Radiation		X		
Dew Point		X		
Relative Humidity		X		
Barometric Pressure		X		

TABLE 9 Air resources monitoring equipment

Parameter	Instrument	Location
Wind Speed and Direction	MRI Model 1022 Anemometer	A-6 (10 & 30M)
Wind Speed, Direction, and Temperature	MRI Model 1071 Mechanical Weather Station	A-11 (10M) A-13 (10M)
Wind Variance	MRI Model 1022/R.M. Young and AeroVironment Sigma Meter	A-6 (30M) A-4 (10M)
Temperature and Lapse Rate	MRI Thermistors w/R.M. Young Shield	A-6 (10 & 30M) A-4 (10M)
Dew Point	EG&G Model 880 Hygrometer	A-6
Suspended Particulates	General Metals Model 5000 HiVol w/Constant Flow Control	A-6
Sulfur Dioxide	Tracor 270 HA Sulfur Analyzer-Gas Chromatography	A-6
Nitrogen Oxides	Monitor Labs Model 8440 NO_x Analyzer Chemiluminescence	A-6
Hydrocarbons	Beckman 6800 Gas Chromatograph, Flame Ionization	A-6
Carbon Monoxide	Beckman 6800 Gas Chromatograph, Flame Ionization	A-6
Oxidants	Montor Labs 8410, Ozone Analyzer, Chemiluminescence	A-6

4.2.1.3 Present Status and Plan for Next Six Months. During the period January 16, 1977 to April 30, 1977, air quality monitoring was performed according to the Work Plan for the Interim Monitoring Program. All measurements activities continued on the schedule of continuous or regular measurements. Comprehensive calibration of all air monitoring instruments was performed according to the schedule indicated above.

The extent of the data collected during this period is tabulated in Table 10. This table lists the percentage of hours during this period that data collection was underway for each parameter. Calibration time is counted as data collection time.

The months of January for winter and April for spring are presented as representative as was done during the Baseline Monitoring Program. The period January 16-January 31, 1977 is considered the month of January in the following discussions.

The plans for the next 6 months are to continue the present program as indicated in the Interim Monitoring Program. The quality assurance calibration tests will continue on schedule. No major changes in the Work Plan are anticipated.

A final report will cover the entire period from January 16 to October 31, 1977. All data not present in this report will accompany the final report. A detailed comparison of Baseline and Interim period data will be presented.

TABLE 10. Percentage of time monitoring was performed during the period 15 January - 30 April 1977.

Component	# of Stations	Percentage
SO_2	1	100
H_2S	1	99.9
Total HC	1	100
NO_x	1	84.7
O_3	1	99.9
Suspended Particulates	1	100
Wind (10m)	4	100
Wind (20m)	1	100
Wind (30m)	1	100
Temp. (10m)	4	100
Δ Temp (30-10m)	1	100
Rel. Hum. (10m)	1	99.9

4.2.1.4 Data Summary.

a. Gaseous Pollutants

Both gaseous and particulate air quality measurements were made at Station A-6. There are no Utah State air quality standards for gaseous pollutants, while Federal standards exist for all components except H_2S. For reference in the ensuing discussions, Table 11 presents the Federal Ambient Air Quality Standards (AAQS) for the various gaseous pollutants monitored on the tracts. For H_2S, a reference for interpreting the data is the California 1-hour standard of 42 $\mu g/m^3$ (.03 ppm).

During this study period, except for sporadic occurrences of high non-methane hydrocarbon (NMHC), the air on the tracts was relatively clean with respect to gaseous pollutants. The only other pollutant that was present in measurable quantities was ozone, which has a natural non-zero background level. Otherwise, almost all instruments measuring gaseous pollutants were recording at their threshold limit most of the time.

Qualitative comparisons were made with the Baseline Monitoring Program data to determine any significant changes in results, although no detailed analysis will be made until the final report. Generally the data do not exhibit any significant abnormalities from the Baseline data. Specific comments are included with the discussion of each parameter when appropriate.

A plot of diurnal variations of O_3 at Station A-6 in January and April are presented in Figures 12 and 13. The average diurnal trend consists of low readings of about 40 $\mu g/m^3$ between 0500-0600 MST

TABLE 11. Federal air quality standards for gaseous pollutants.

Pollutant	Averaging Time	Primary Standards	Secondary Standards
Ozone (O_3)	1 hour	160 µg/m^3 (0.08 ppm)	Same as primary
Carbon Monoxide CO	8 hours	10 mg/m^3 (9 ppm)	Same as primary
	1 hour	40 mg/m^3 (35 ppm)	Same as primary
Sulfur Dioxide SO_2	Annual Average	80 µg/m^3 (0.03 ppm)	-
	24 hour	365 µg/m^3 (0.14 ppm)	-
	3 hour	-	1300 µg/m^3 (0.5 ppm)
Nitrogen Dioxide NO_2	Annual Average	100 µg/m^3 (0.05 ppm)	Same as primary
Hydrocarbons (corrected for methane - NMHC)	3 hour (6-9 a.m.)	160 µg/m^3 (0.24 ppm)	Same as primary

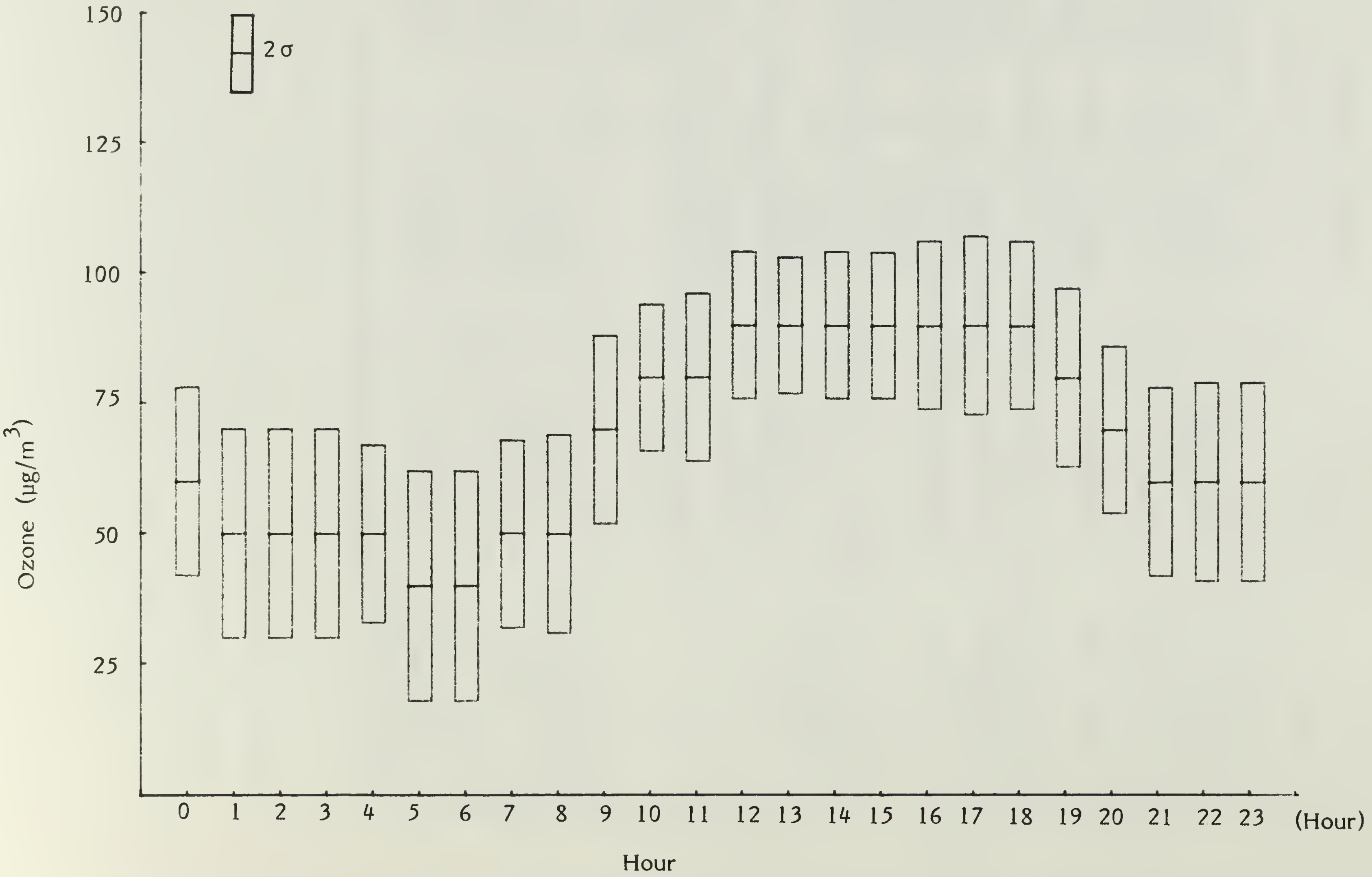


FIGURE 12. Diurnal variation in mean ozone concentrations with their standard deviations at Station A-6 during winter of 1977, based on data for the month of January.

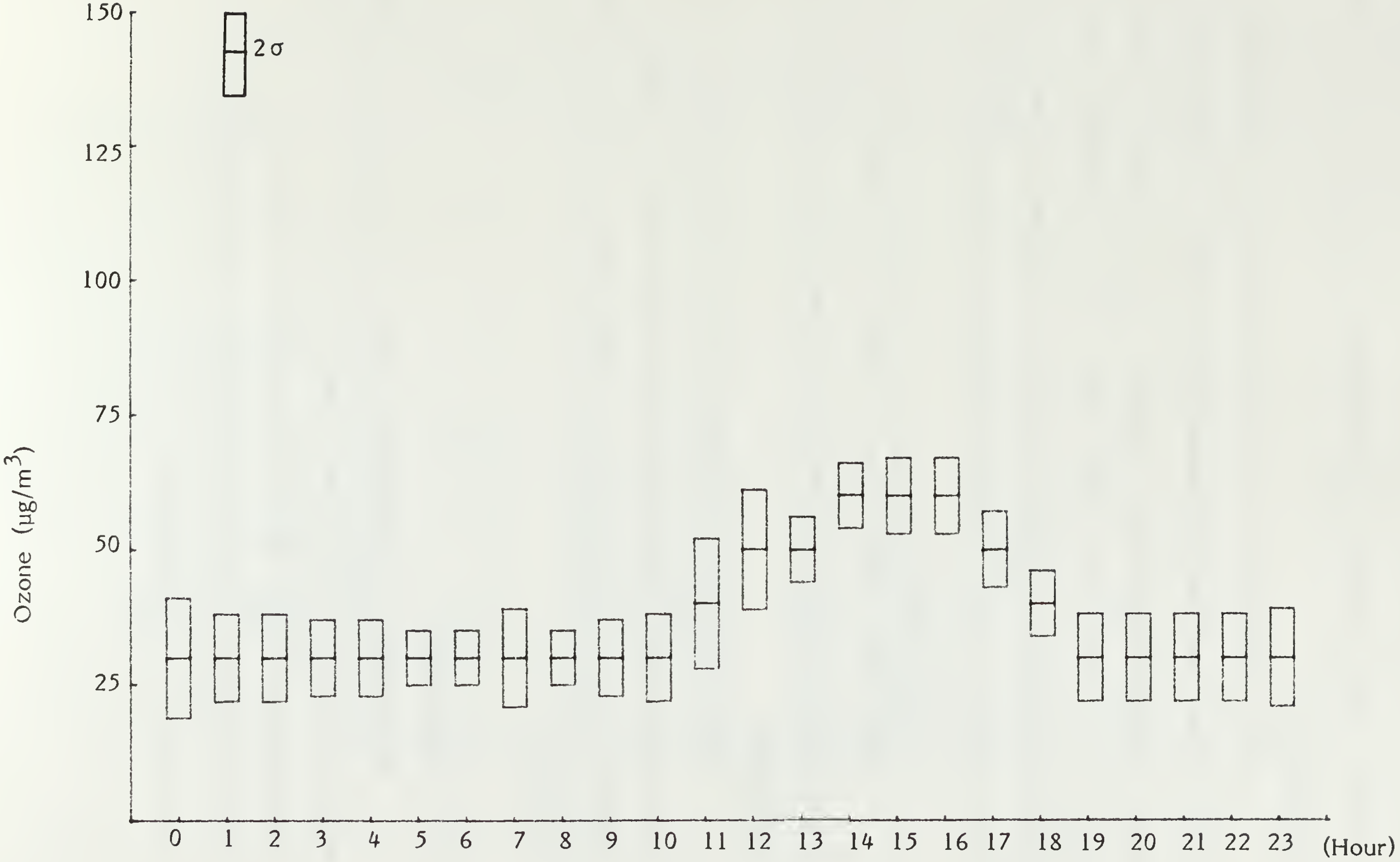


FIGURE 13. Diurnal variation in mean ozone concentrations with their standard deviations at Station A-6 during spring 1977, based on data for the month of April.

in the early morning hours and higher values of 90 $\mu g/m^3$ between 1300-1700 MST in the afternoon. No exceedances of the air quality standard were observed.

Very little diurnal variation was observed for any other pollutant. Table 12 shows the peak and second highest values, as well as the percentage of observations exceeding standards, for all gaseous pollutants observed on the entire tract area. NMHC shows 7% exceedance of the 3-hour National standard. Two days of abnormally high NMHC values occurred on April 22 and 23 at Site A-6 with high values reaching 2300 $\mu g/m^3$.

b. Particulates

Particulate concentrations are monitored by means of high volume sampler which samples over a period of 24 hours once every six days at Station A-6.

Table 13 presents the geometric mean, standard geometric deviation, maximum and minimum of particulate concentrations. None of the recorded values exceeded Federal or State standards, which are presented in Table 14.

4.2.2 Meteorology

Meteorological measurements as part of the two-year Environmental Baseline Monitoring Program were completed January 15, 1977. The program discussed in this section was implemented January 16, 1977. Monitoring equipment and selected specific sites are identical to those used during the Baseline period.

TABLE 12. The peak and second highest values, as well as the percent of observations exceeding standards for all gaseous pollutants, observed on the tracts from 16 January - 30 April 1977.

Component	Averaging Time	Peak Conc.	2nd highest Conc.	Average	Standard	% Exc.
O_3 (µg/m^3)	1 hr	130	120	63	160	0
CO (µg/m^3)	8 hr	0.5	0.5	0.2	10	0
	1 hr	0.8	0.7	0.2	40	0
SO_2 (µg/m^3)	1 hr	10	10	0	-	0
	24 hr	0	0	0	365	0
	3 hr	5	5	0	1300	0
NO_2 (µg/m^3)	1 hr	10	10	0	-	0
NMHC (µg/m^3)	3 hr (6-9a.m.)	1800	1600	60	160	7
H_2S	1 hr	5	0	0	42	0

TABLE 13. The geometric mean, standard geometric deviation, maximum and minimum particulate concentrations ($\mu g/m^3$) from 16 January - 30 April 1977.

Station	Geometric Mean	Standard Geometric Deviation	Maximum	Minimum
A-6	17.8	2.1	43.1	7.6

TABLE 14. Ambient air quality standards for particulate matter ($\mu g/m^3$).

Pollutant	Averaging Time	Utah Standards	National Standards	
			Primary	Secondary
Suspended Particulate Matter	Annual Geometric Mean	90	75	60
	24 hour	200	260	150

4.2.2.1 Objectives. The objectives of continuing meteorological data collection in the Interim Monitoring Program are to extend the meteorological data base, determine trends, extend data collection at A-13 to a full year, and to provide data verification of Baseline data for use in future air pollutant dispersion modeling work.

4.2.2.2 Methods. Figure 11 shows the locations of monitoring sites, and Table 8 summarizes the data to be collected at each station.

These sites are A-4, A-6, A-11 and A-13. The meteorological equipment is shown in Table 9 and is the same as used during the Baseline Program. Meteorological data is collected continuously and recorded on digital punch tapes every 6 minutes. Strip charts are also used at A-4 and A-6 for a backup record.

4.2.2.3 Present Status and Plans for Next Six Months. The discussion presented in Section 4.2.1.3 applies for meteorological monitoring as well.

4.2.2.4 Data Summary. Quantitative comparisons were made with the Baseline Monitoring Program data to determine any significant changes in results, although no detailed analyses will be made until the final report. Generally the data do not exhibit any significant abnormalities from the Baseline data.

a. Surface Meteorology

Typical airflow patterns observed on the tracts during the early morning and afternoon in January and April are presented in Figures 14 through 17. The solid arrows in these figures are wind vectors at monitoring sites, and the longer lines are estimated flow streamlines. There was no noticeable difference between the two months except that wind speeds in April were usually higher. Generally, in the morning hours, air flow was the drainage type, flowing toward low terrain and down the White River Channel. The afternoon winds were stronger and were dominated by the synoptic scale pressure gradient. A west to east airflow pattern can be recognized throughout the tracts.

The diurnal variation of mean wind speed and its standard deviation at Site A-6 for January and April are plotted in Figures 18 and 19. During April high winds were observed.

Figures 20 and 21 present directional wind roses at all wind stations on the tracts for January and April. The predominance of drainage type winds is clearly shown. The month of January, 1977 exhibits stronger drainage type wind structure than the month of April.

Temperature. Figures 22 and 23 present the diurnal variation in temperature in January and April at Site A-6. Comparing the two months' data will show that temperatures were higher in April than in January, as expected. Average nighttime values were around -5.7°C in January and 5.2°C in April. Average afternoon values were around 3.3°C and 15.7°C, respectively. The daily maximum temperature was generally observed at 1400-1500 MST, while the daily minimum was observed between 0500-0700 MST.

Relative Humidity. Plots of the diurnal variation in relative humidity in January and April at Site A-6 are presented in Figures 24 and 25. Nighttime relative humidity was around 81% in January and 62% in April, while the afternoon relative humidity was about 44% and 28%, respectively.

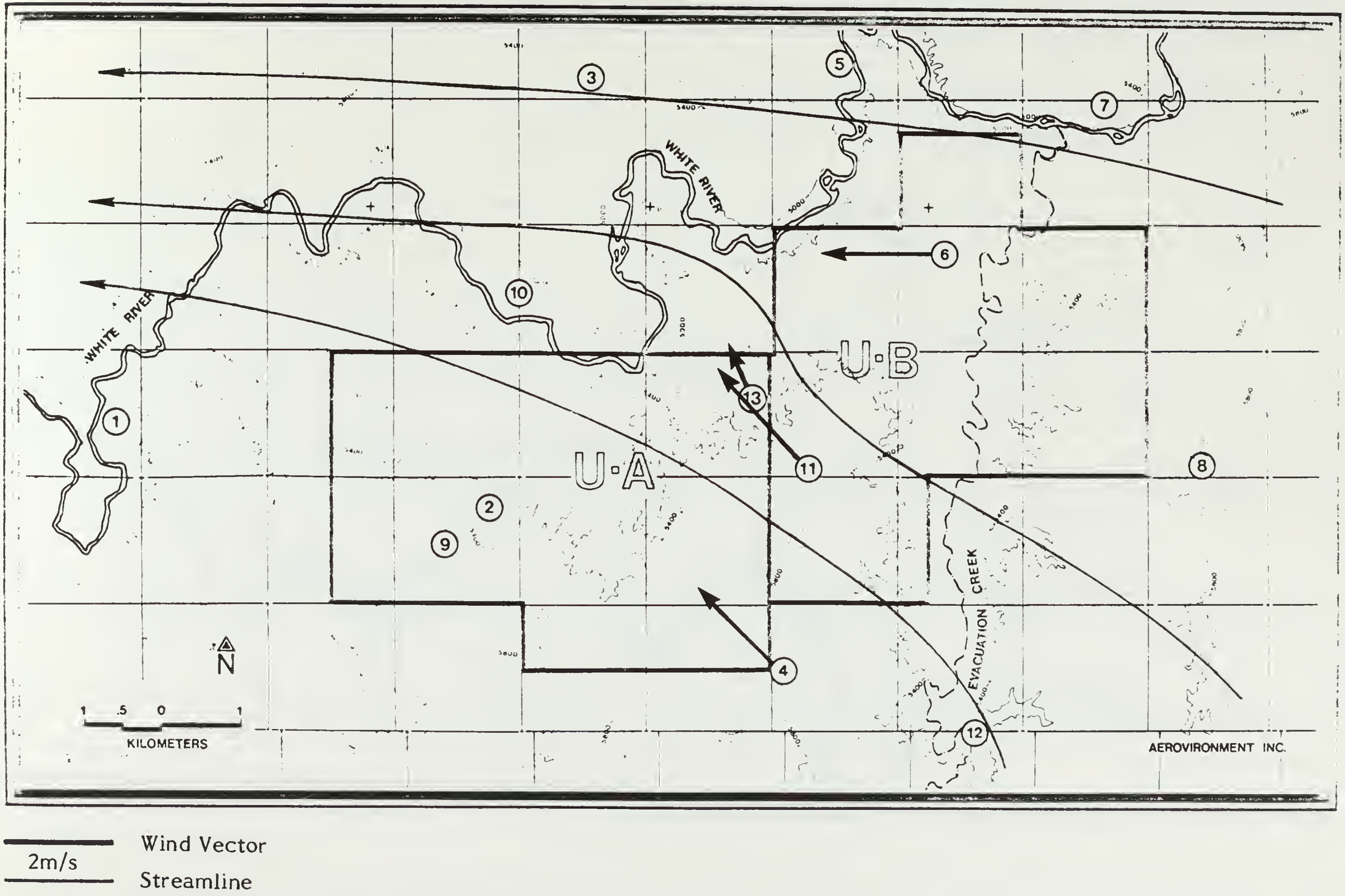


FIGURE 14. Typical airflow pattern on the tracts Ua and Ub in the morning in January 1977.

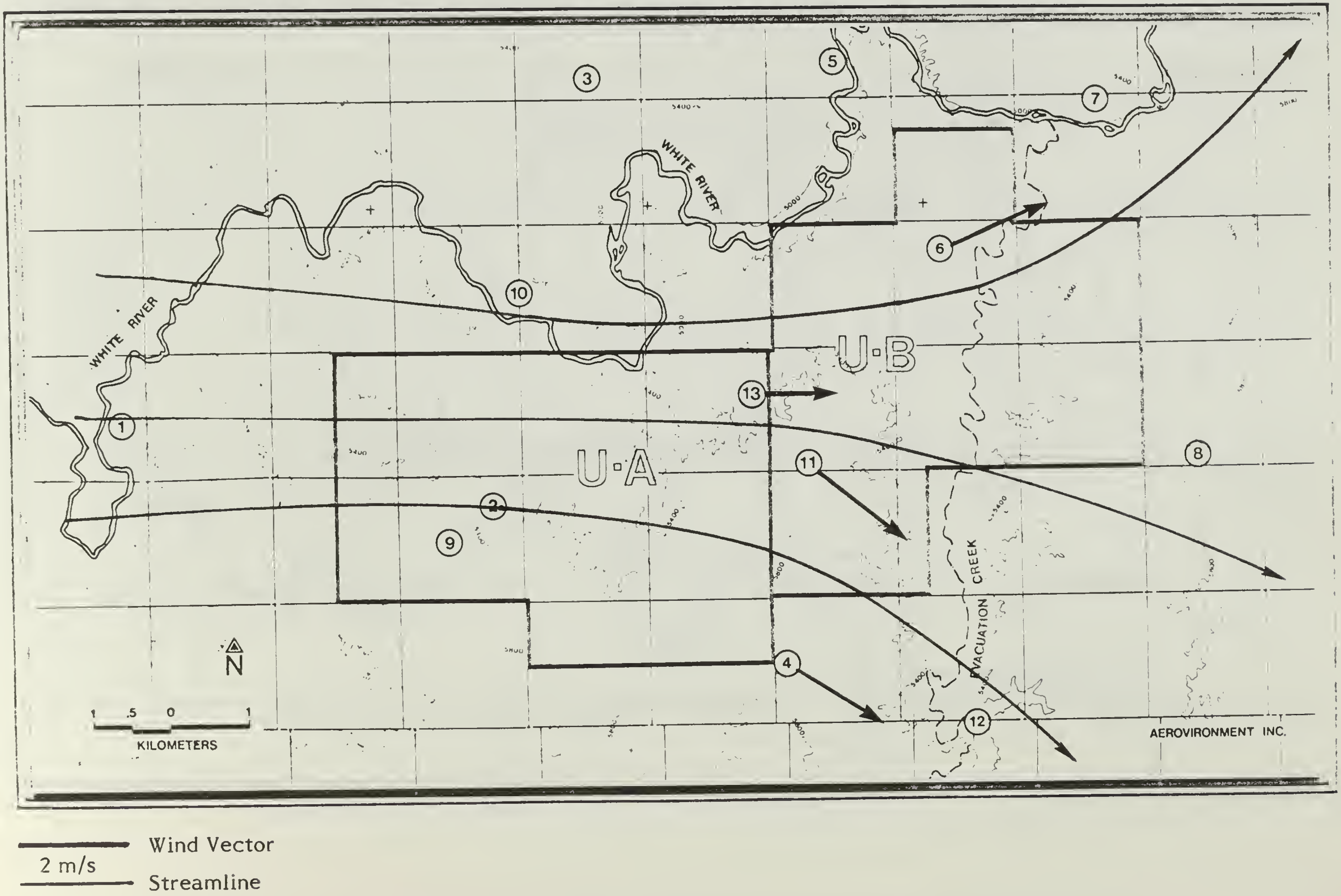


FIGURE 15. Typical airflow pattern on the tracts Ua and Ub in the afternoon in January 1977.

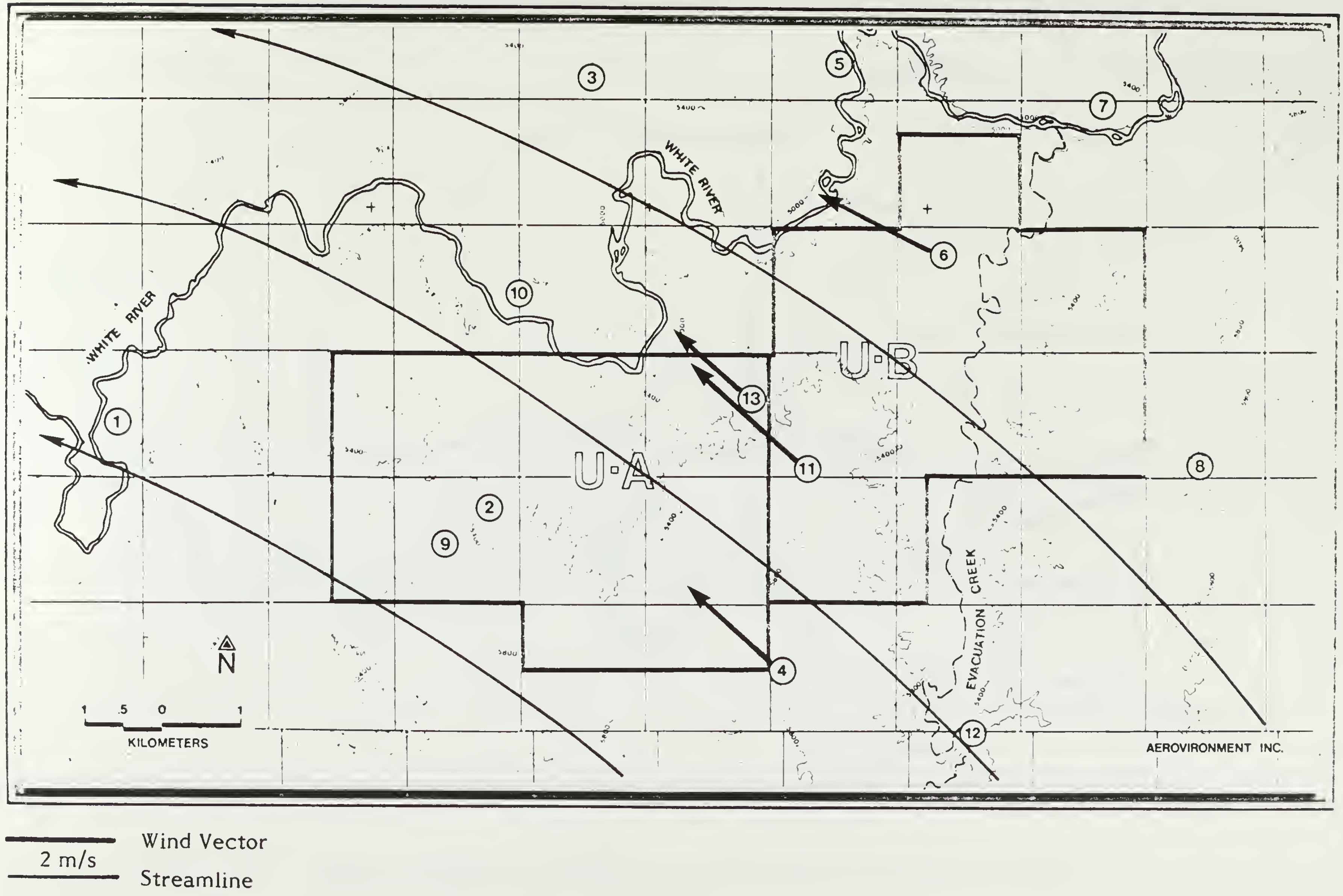


FIGURE 16. Typical airflow pattern on the tracts Ua and Ub in the morning in April 1977.

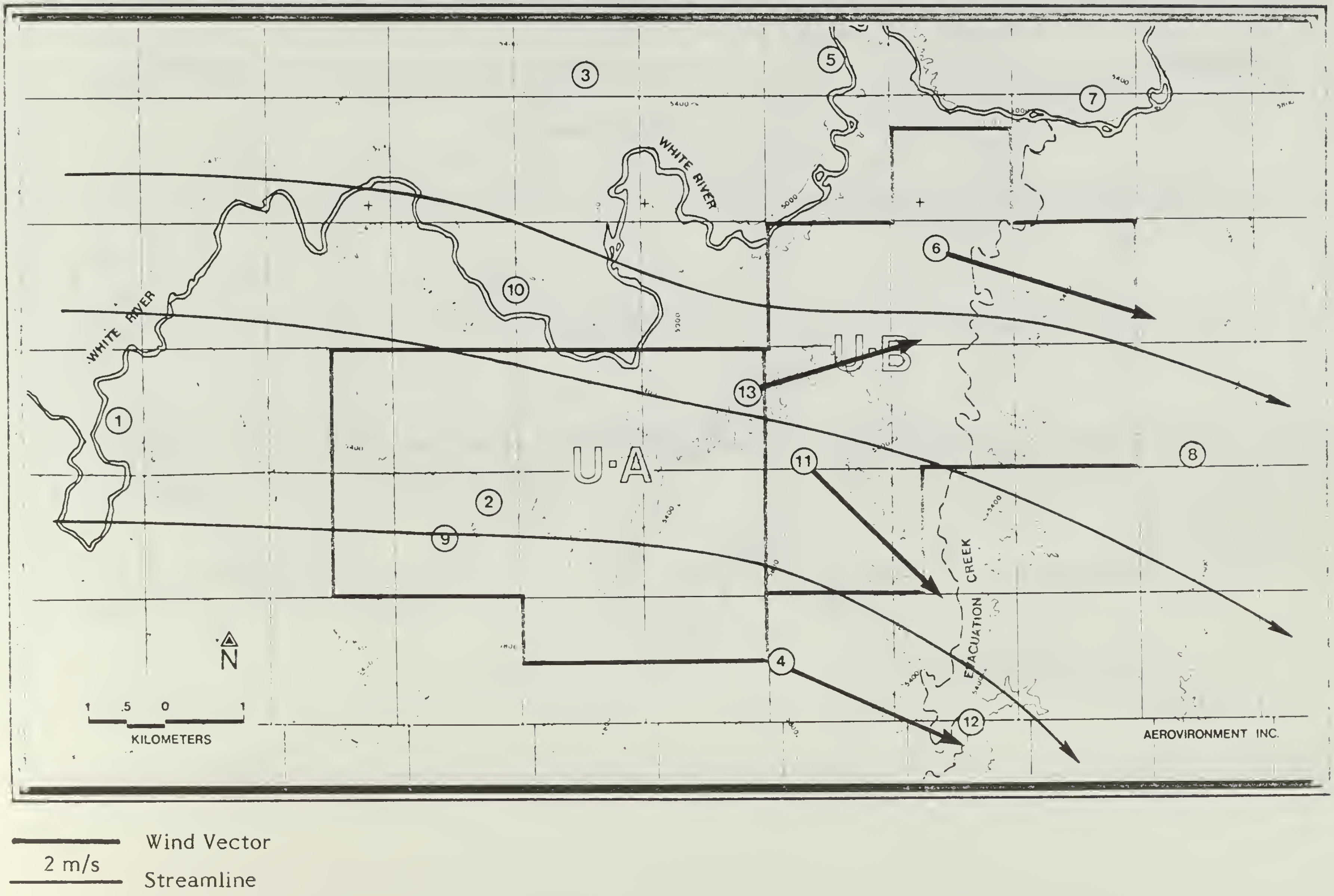


FIGURE 17. Typical airflow pattern on the tracts Ua and Ub in the afternoon in April 1977.

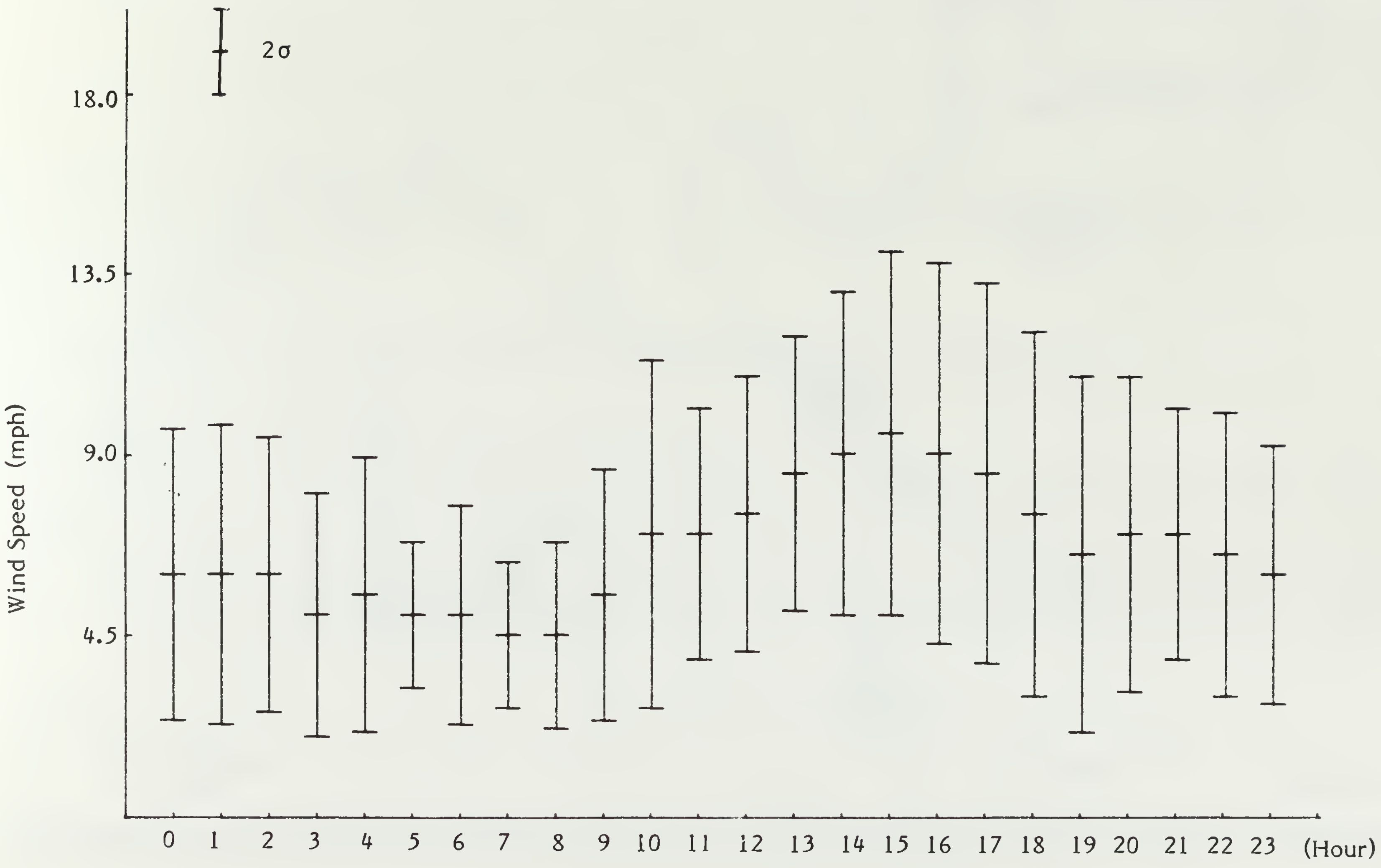


FIGURE 18. Diurnal variations of wind speeds and their standard deviations at Station A-6 in January 1977, a typical winter month.

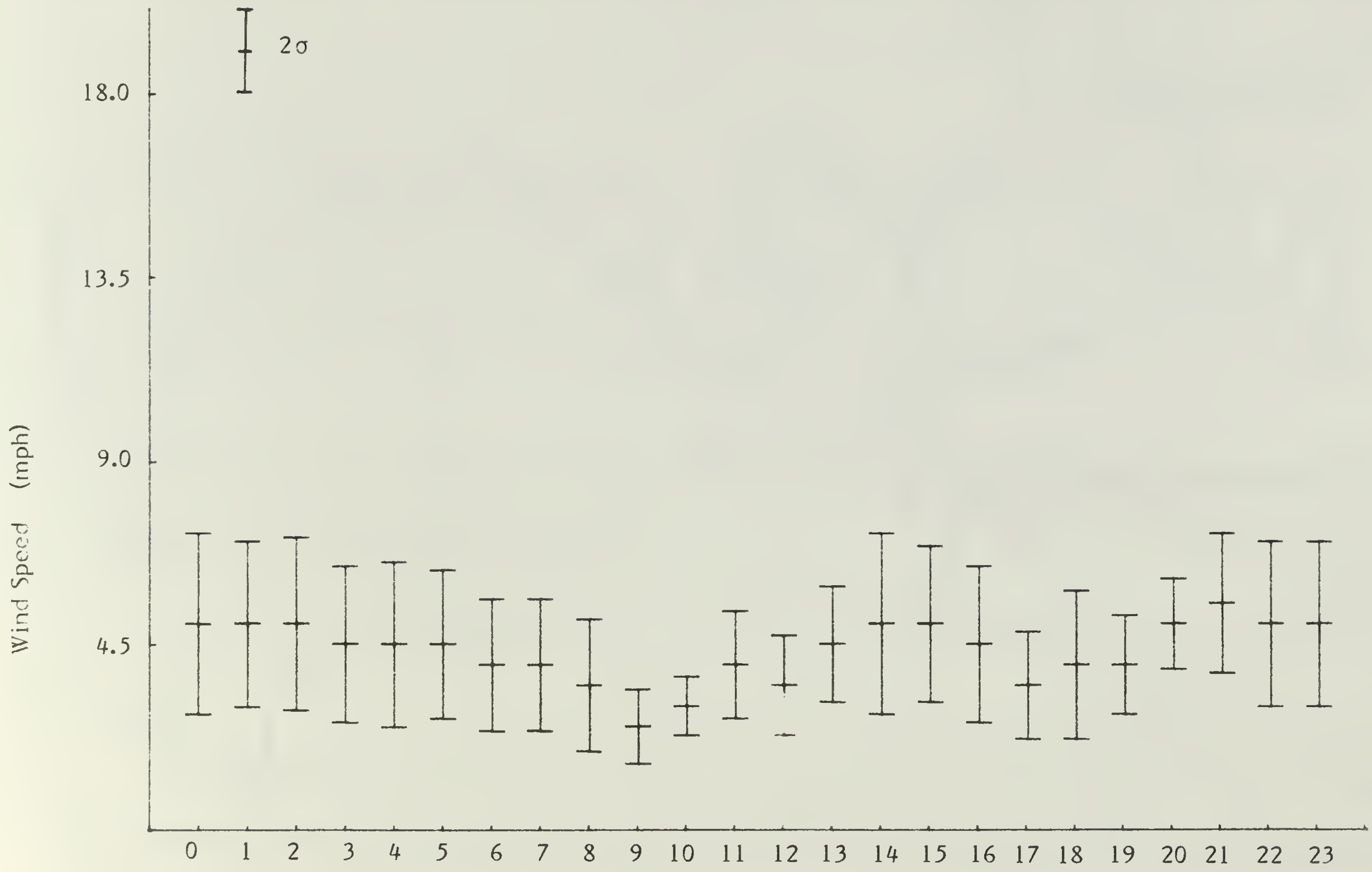


FIGURE 19. Diurnal variations of wind speeds and their standard deviations at Station A-6 in April 1977, a typical spring month.

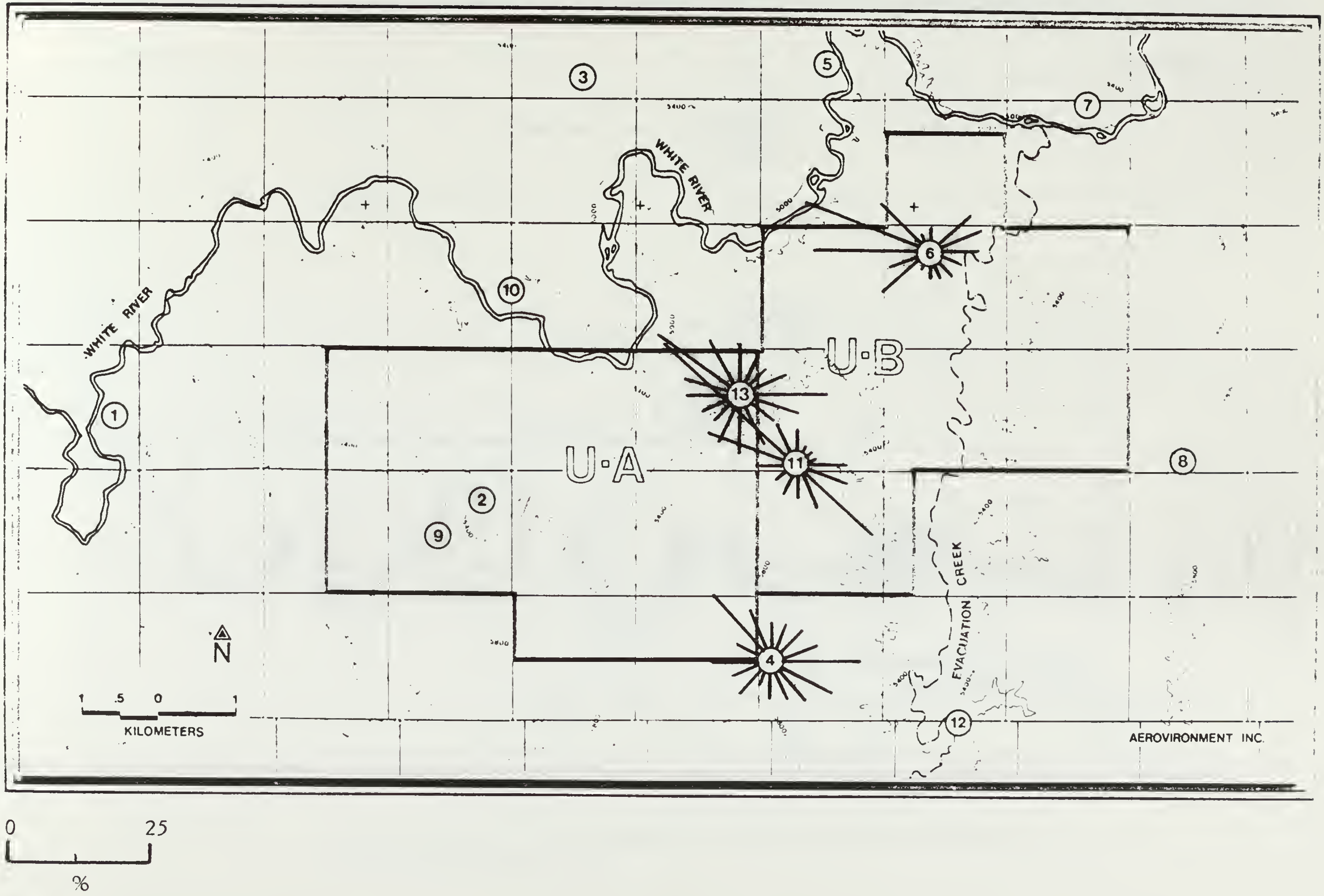


FIGURE 20. Directional wind roses at the monitoring stations on the tracts for January 1977. The length of each bar represents the frequency of winds from the direction toward which the bar points.

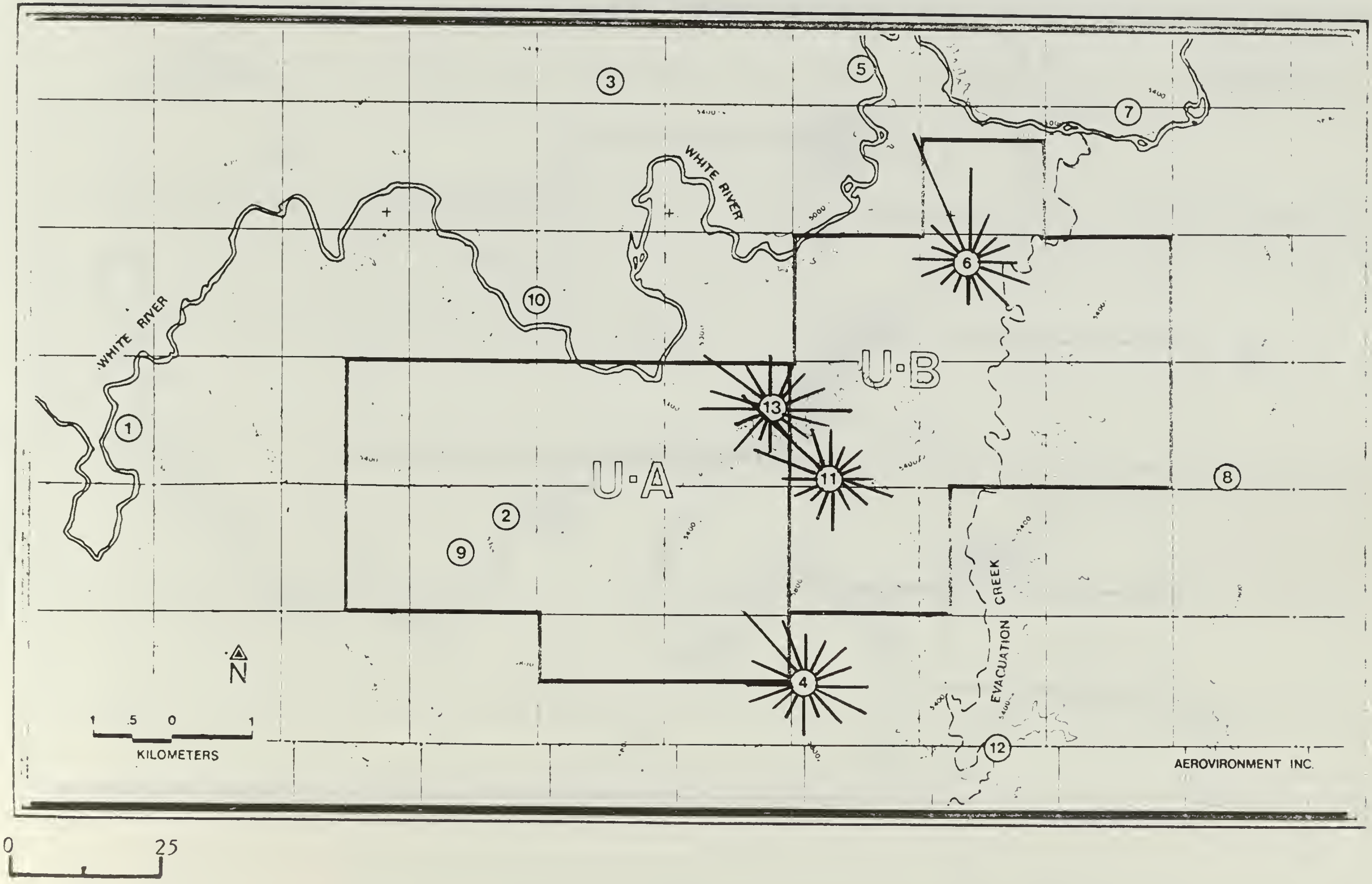


FIGURE 21. Directional wind roses at the monitoring stations on the tracts for April 1977. The length of each bar represents the frequency of winds from the direction toward which the bar points.

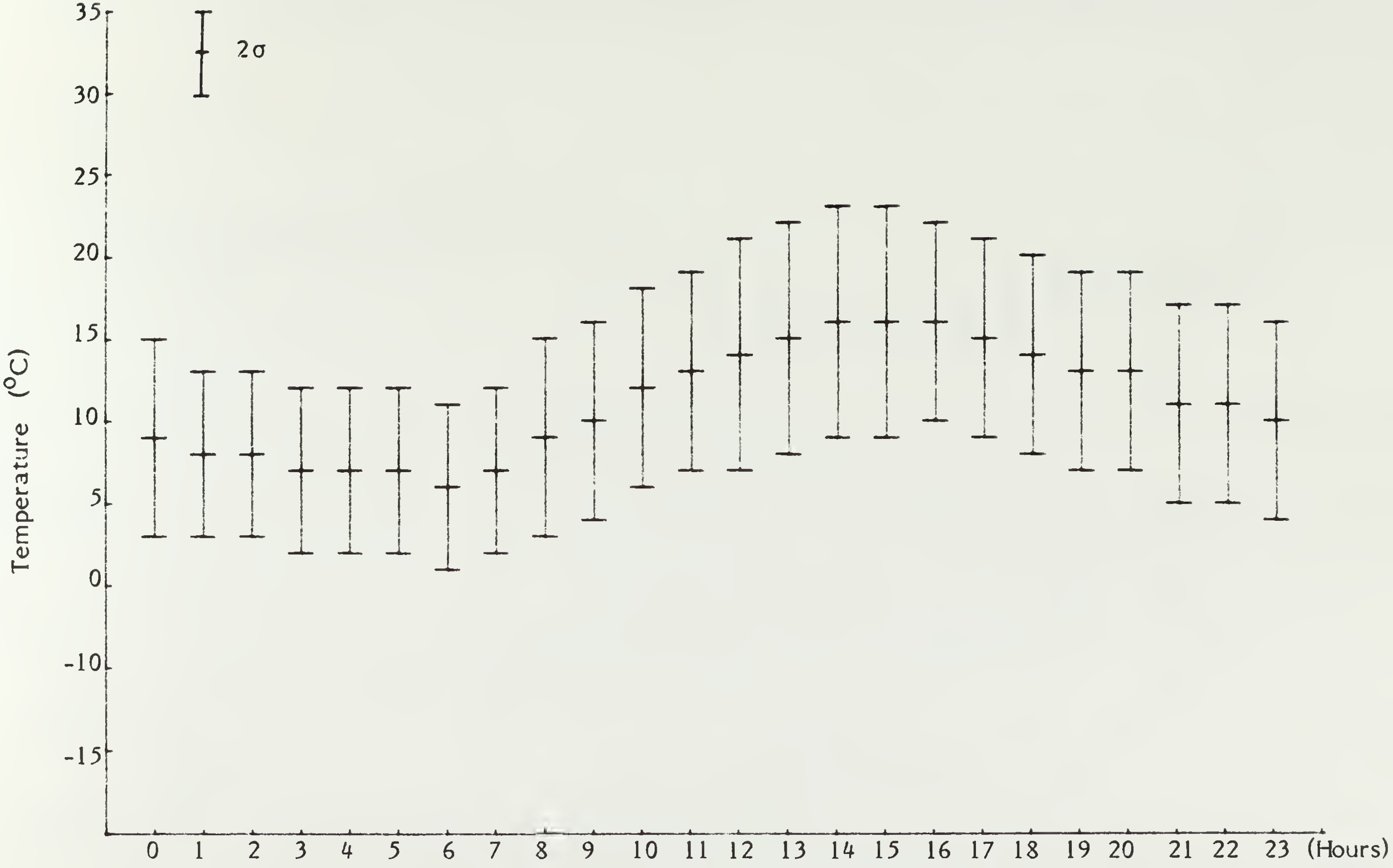


FIGURE 22. Diurnal variation of mean temperatures and their standard deviations at Station A-6 in January 1977.

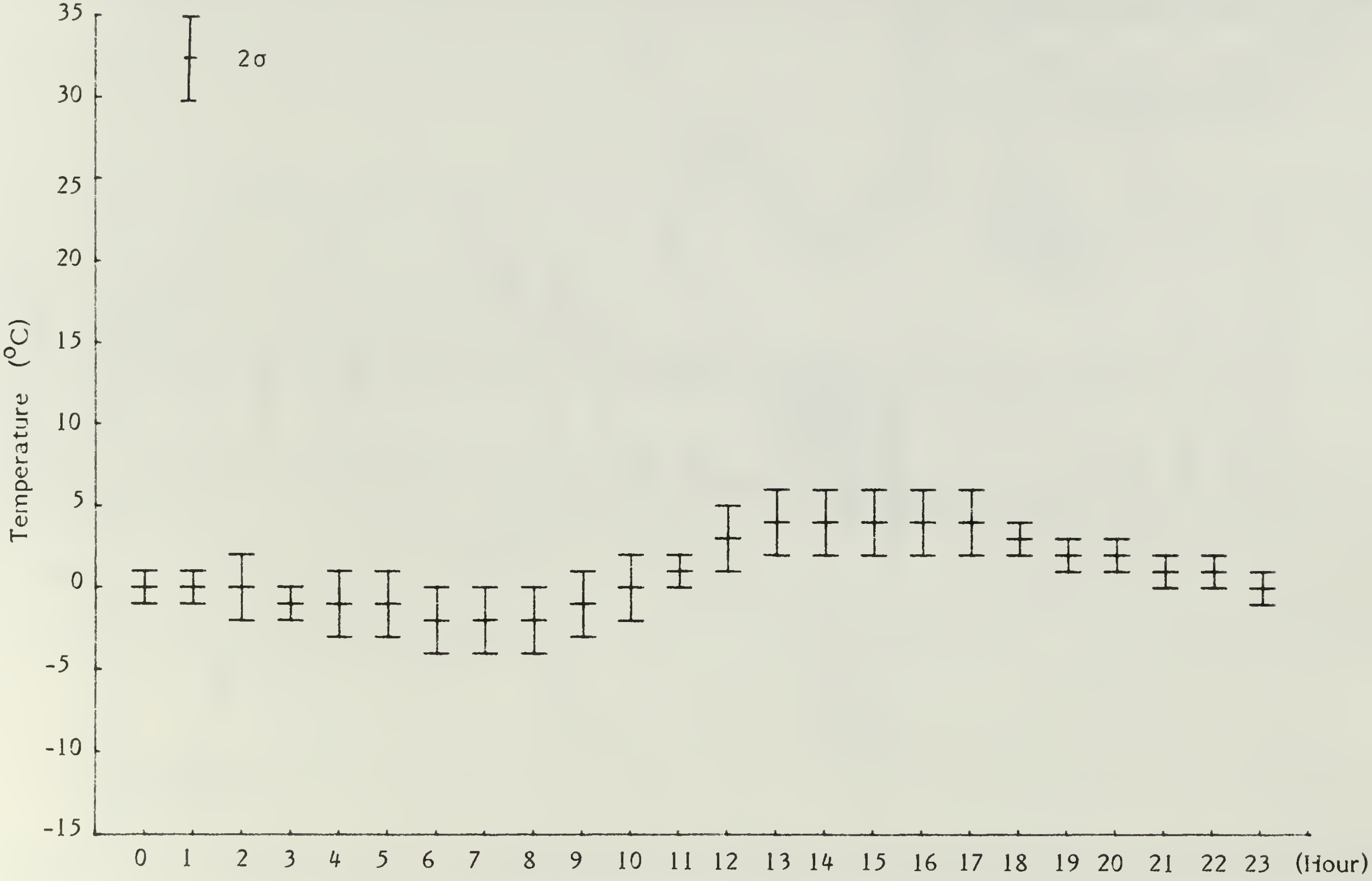


FIGURE 23. Diurnal variation of mean temperatures and their standard deviations at Station A-6 in April 1977.

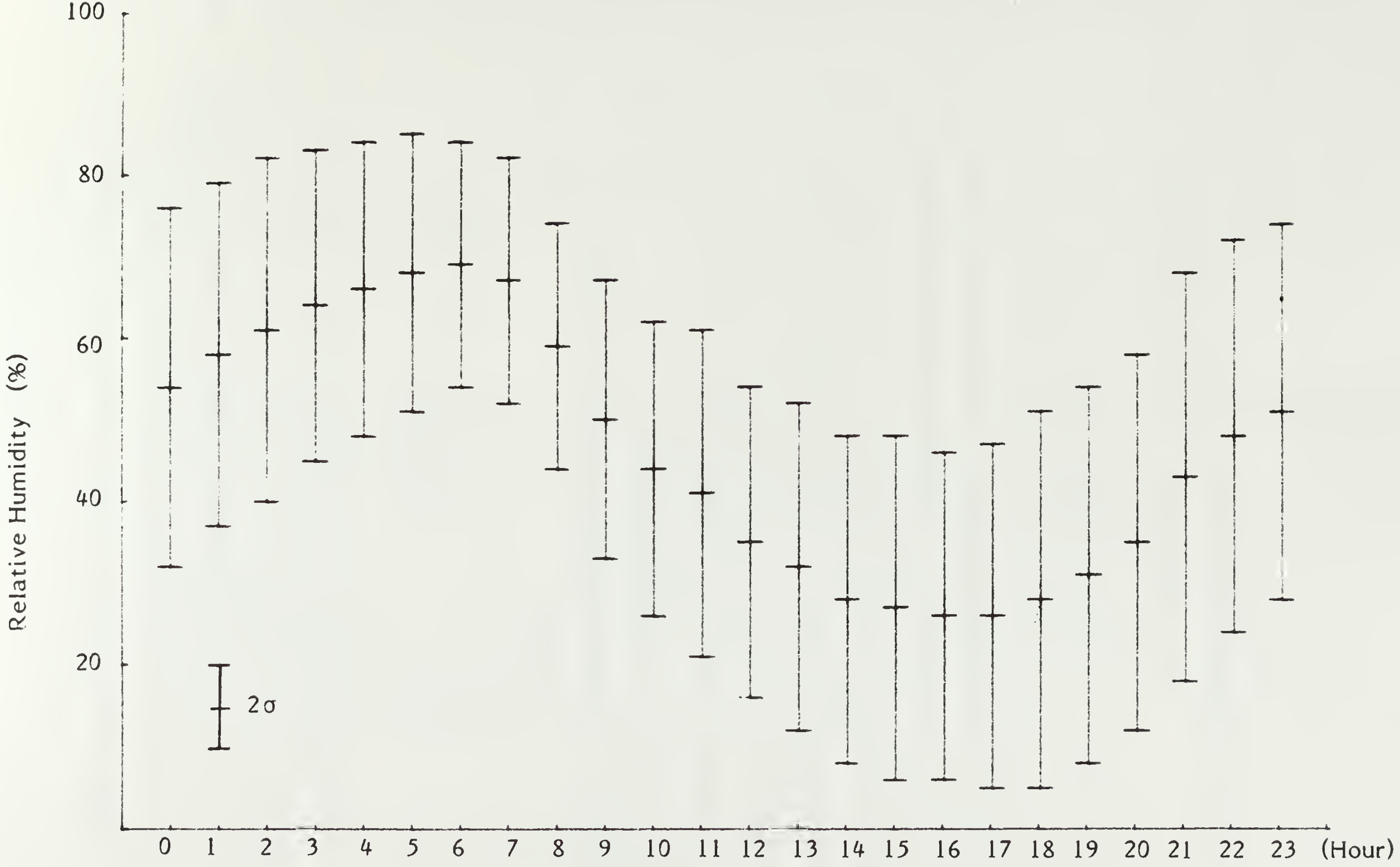


FIGURE 24. Diurnal variation of mean relative humidity readings and their standard deviations at Station A-6 during January 1977.

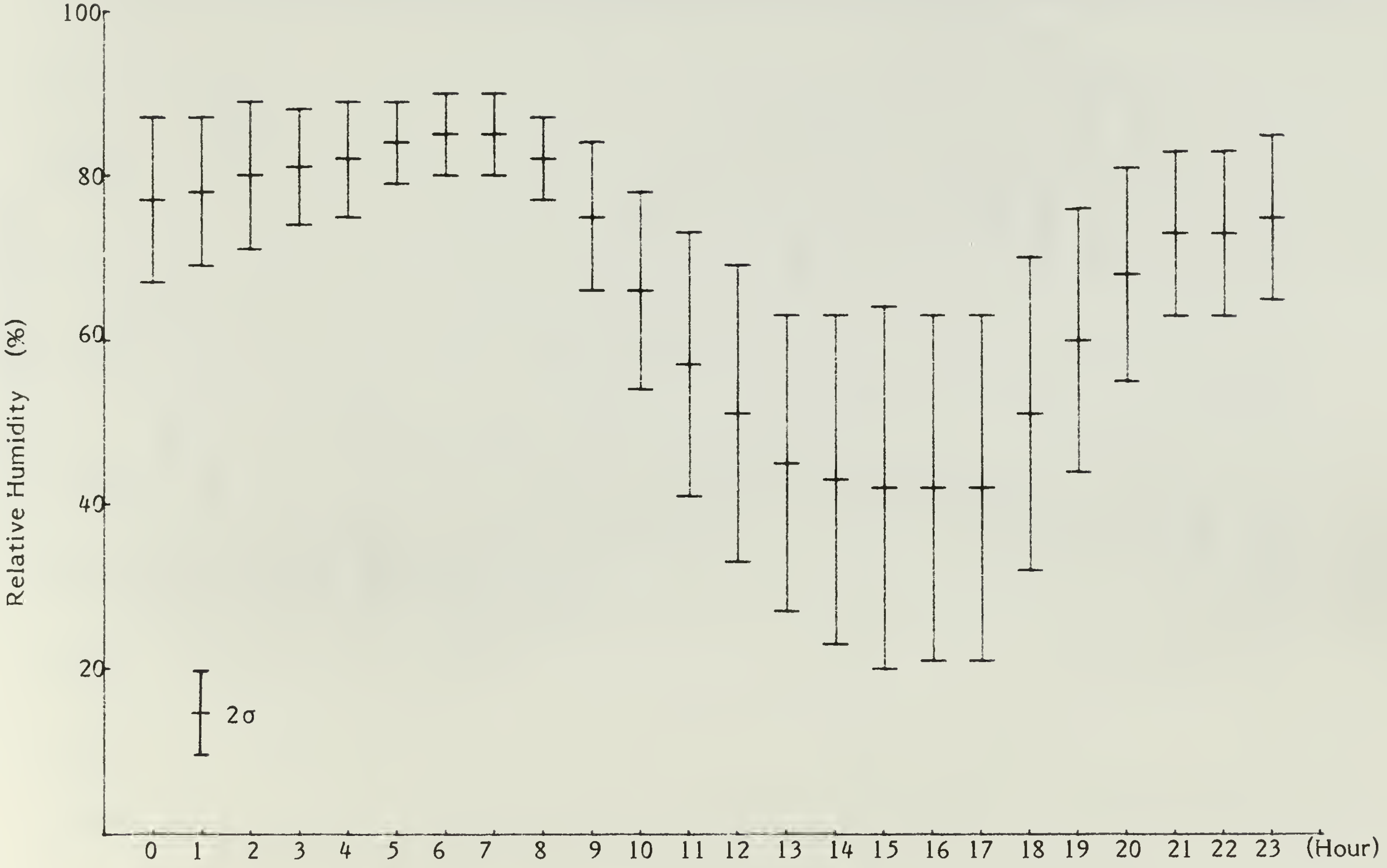


FIGURE 25. Diurnal variation of relative humidity readings and their standard deviations at Station A-6 during April 1977.

This diurnal trend is a mirror image of the temperature plot in Figures 22 and 23, which indicates that the amount of water vapor in the air remained approximately constant during the day.

b. Diffusivity

The dispersion of a plume is often described mathematically by the diffusion equation having the following form:

$$\frac{X}{Q} = \frac{1}{\pi \sigma_y \sigma_z U} \exp \left[- \frac{1}{2} \left(\frac{H}{\sigma_z} \right)^2 \right]$$

where X is the surface concentration, Q is the source emission rate, σ_y, σ_z are horizontal and vertical dispersion coefficients respectively, U is the mean wind speed, and H is the effective stack height. MacCready, et al (1974) show that, at downwind distances in excess of the order of a kilometer, $\sigma_y^2 \sim \sigma_v t$ and $\sigma_z^2 \sim \sigma_x t$ where σ_v and σ_w are the root-mean-square turbulence fluctuations in the lateral wind speed v and the vertical wind speed w and t is the time of plume travel. Using these relations for H = 0, and noting that the location of a receptor is given by x = Ut, one can write

$$\frac{X}{Q} \sim \frac{1}{(\sigma_v \; \sigma_w)^{1/2} x}$$

This relationship, with H taken as zero, is valid along the centerline of a plume released aloft, or at the surface for emissions released also at the surface (although ground effect makes the constant of proportionality twice as great in the latter case as in the former). For other cases the decay in X/Q with x is even greater because of the growth of σ_z in the exponential term of the full equation.

For receptors off of the plume centerline, an exponential term, which includes concentration decay with lateral distance, y, from the centerline

$$\exp\left(-\frac{ky^2U}{\sigma_v x}\right)$$

must be included in the analysis. Its impact will always be such as to decrease the concentrations expected.

Using this approach, a quantitative characterization of diffusivity on the tracts is possible, using the measurements of σ_v ($\sigma_v \approx U\sigma_\theta$) and of σ_w made continuously at Station A-6. Tables 15 and 16 present the frequency distributions of the quantity $(\sigma_v\sigma_w)^{1/2}$, which is inversely proportional to X/Q, for winter (January) and spring (April) seasons of 1977 at Station A-6.

No significant changes in the quantity $(\sigma_v\sigma_w)^{1/2}$ were identified from the Baseline data.

TABLE 15. Relative frequency distribution (%) of $\sqrt{\sigma_v \sigma_w}$ (m/s) at Station A-6 for Winter 1977. All measurements were made at 30 m above the surface. All hours of the day are included.

$\sqrt{\sigma_v \sigma_w}$ Range*	0.00	0.20	0.40	0.60	0.80	1.00	1.20	>1.20	Total No. of Observations
% Frequency	8	72	19	1	0	0	0	0	384

TABLE 16. Relative frequency distribution (%) of $\sqrt{\sigma_v \sigma_w}$ (m/s) at Station A-6 for Spring 1977. All measurements were made at 30 m above the surface. All hours of the day are included.

$\sqrt{\sigma_v \sigma_w}$ Range*	0.00	0.20	0.40	0.60	0.80	1.00	1.20	>1.20	Total No. of Observations
% Frequency	3	46	20	18	10	3	.1	0	720

* Each interval of $\sqrt{\sigma_v \sigma_w}$ spans 0.20 m/s and commences with the value shown.

4.3 BIOLOGICAL RESOURCES

Biological resources monitoring for the two-year Environmental Baseline Monitoring Program was completed during January of 1977.

Interim monitoring work involves vegetation and terrestrial vertebrates. Data from a USGS Water Resources Division aquatic biology monitoring program will be incorporated into the data base. Data from ongoing Utah Division of Wildlife Resources and Bureau of Land Management programs will also be reviewed and incorporated as applicable.

The monitoring work used techniques similar to those used in the Baseline program.

Figure 26 shows the monitoring sites for vegetation and animal monitoring activities (except large mammal sampling quadrats). There were some changes made from the program as presented in the December 1976 Work Plan. These will be discussed in the appropriate sections that follow.

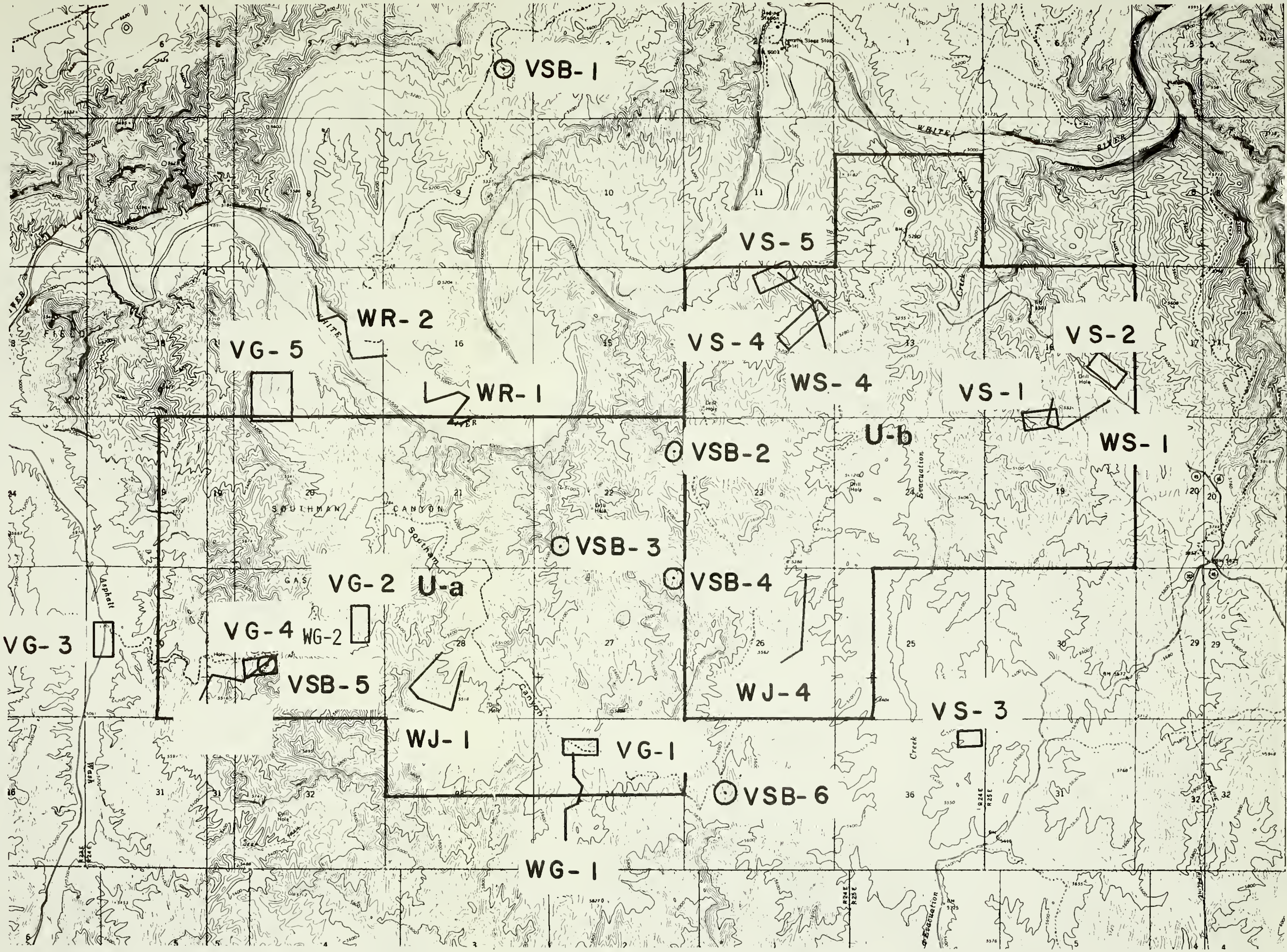
4.3.1 Vegetation

The following describes the monitoring to be done on the vegetation sites shown in Figure 26. Work in the course of the Revegetation Study Program will supplement this monitoring.

4.3.1.1 Objectives. The major objectives are to maintain continuity of key parameter data collection, determine trends, develop supportive vegetation data for animal monitoring results, and to explore "control" versus "treatment" system of monitoring oil shale development impacts. The last objective holds the promise of factoring out natural cyclic trends while determining true net impacts of development operations.

FIGURE 26

VEGETATION/VERTEBRATES MONITORING SITES



LEGEND

☐ = VEGETATION - GREASEWOOD JUNIPER SHADSCALE

/\/ = WILDLIFE

⊙ = VEGETATION - SAGEBRUSH

4.3.1.2 Methods. During the period of lease suspension the task of monitoring vegetation is to consist of the following:

A. Measurement of productivity of annual plant species.

B. Measurement of leader growth of big sagebrush, a dominant shrub on Tract Ua/Ub.

C. Measurement of percent of stems browsed on shrubs measured in B.

D. Perform visual surveys of general nature in regard to vegetation conditions, including

- seed production
- seedling establishment
- animal utilization
- any unusual buildup of insects or plant disease or early seasonal dormancy.

At the peak of annual growth in the spring (June) annual species will be clipped from approximately 200 .5 m^2 plots in areas previously sampled during the Baseline study located in the sagebrush/greasewood vegetation type and the shadscale/sagebrush type. Sampling will be done in the same manner as in the Baseline inventory. Three areas in Section 22 will be included in the sampling for productivity of annual plants. These areas will correspond to the sagebrush stem growth transects. Sampling of the juniper type may be necessary but will depend upon the favorability of the growing season. In 1976 annual plant species productivity in the juniper type was extremely low; thus, an ocular estimate would be adequate under such circumstances.

In the fall (September-October) current year's stem growth of big sagebrush will be measured in a paired-plot arrangement on an adequate number of sagebrush plants along three transects in the zone of influence of the proposed industrial site (in Section 22) and on three transects in areas surrounding that site. This will allow a comparison of stem growth in and around the proposed industrial site and in surrounding areas.

During the time of productivity sampling in the spring and the measurement of stem growth in the fall, an ocular reconnaisance of vegetation conditions on the tracts will be made. Reproduction, plant growth and vigor, and any excess animal utilization will be noted. Quantitative data will be obtained to validate any visual observations as required. Observations of vegetation condition may also be conducted as an ongoing activity during revegetation study.

4.3.1.3 Data Analysis and Reports. Data will be summarized and subjected to a statistical analysis utilizing a t-test procedure[1/]. Productivity data and plant measurements from plots in the expected impact area and those from the non-impact area will be compared. Obviously, no difference would be expected in 1977 but a procedure would thus be established and evaluated for future use.

The number of plots or plants required for sampling within 20 percent of the mean at a 90 percent probability level will be determined, and will probably be less than 200. Data from the 1975 and 1976 Baseline inventory will serve as a guide to the actual number of plots or plants necessary in the 1977 inventory.

A comparison of results obtained in 1977 will be made with data provided in the 1975 and 1976 Baseline reports.

[1/] Snedecor, G. W. 1967. Statistical Methods. 6th Edition, Iowa State College Press. Ames, Iowa.

The vegetation work will be reported in the final report. This report will cover the period January 16, 1977 - October 31, 1977.

4.3.2 Terrestrial Biology

All portions of the required two-year Environmental Baseline Monitoring Program were completed by January 15, 1977. Most of the work was completed by October 1976.

The Interim Monitoring Program concentrates on birds and mammals. No further work is planned during the suspension period on reptiles, amphibians or aquatic biology.

The USGS, however, is conducting an aquatic biology survey near the tract. The data from this program, and applicable programs conducted by the Utah Division of Wildlife Resources (DWR) and/or Bureau of Land Management, will be incorporated into the WRSP data base.

Figure 26 shows the location of sampling sites.

4.3.2.1 Objectives. The major objective of the program is to extend the data base on selected birds and mammals so as to investigate population trends noted during the Baseline period. Other objectives are to evaluate control-treatment monitoring techniques which would allow for distinguishing directly between natural cyclic changes and changes attributable to oil shale development activities.

4.3.2.2 Methods. The program gathers data in the following areas:

1. Density estimates for species, genera, family, order and vertebrate class;
2. Identification of species, genus, etc.;
3. Spatial distribution of species, genus, etc. throughout the tract; and,
4. Seasonal activity of species, genus, etc.

The test design for collection of appropriate data is based upon four sampling techniques. Flushing transects were employed in February and April to monitor bird and diurnal mammal populations. The April transect was added to the work scope after the Work Plan was published. This addition was prompted by the unusual changes in weather conditions which occurred from January to April. Two more collection periods are planned for June and August. Small (5 x 5) live-trap grids were used in February and April and are planned for June and August, with large (12 x 12) live-trap grids to be used once in August to monitor small nocturnal rodents. A large mammal aerial survey was planned for December 1976 to provide density and distributional information on mule deer, other large mammals and raptors. Poor weather conditions prevented this survey from being carried out. The four techniques are described according to sampling location (defining distribution), frequency (defining seasonal activity), and intensity (defining density).

Flushing transects will be used to monitor bird and diurnal mammal populations at eight locations. There are eight 1 km flushing transects on the tract and within the one mile boundary area. These transects are located in the following vegetation associations:

1. Juniper vegetation in Southam Canyon (WJ-1);
2. Juniper vegetation east of Southam Canyon (a new location) (WJ-4);
3. Greasewood vegetation in Southam Canyon (WG-1);
4. Greasewood vegetation in Southam Canyon (WG-2) (this site replaces WG-4 cited in the Work Plan -- WG-4 could not be extended as originally planned.)
5. Shadscale vegetation near the eastern border of Tract Ub (WS-1);
6. Shadscale vegetation south of Ignatio Stage Stop (a new location) (WS-4);
7. Riparian vegetation in White River bottomland (WR-1);
8. Riparian vegetation, off-site; in White River bottomland (WR-2).

The specific transect locations (Figure 26) are primarily designed to allow for adequate coverage of Tract Ua/Ub in extending the Baseline data base. Secondarily, some locations can be designated as control-treatment sites during shale processing. Two transects in Southam Canyon (WG-1 and WJ-1), the area for spent shale disposal, will monitor changes within the treatment area. Two other transects to the east (WJ-4) and the west (WG-2) of Southam Canyon will be control sites. No activities are planned in the former area throughout Tract Ua/Ub development, while WG-2 will not be impacted until quite sometime into the development period. WS-1 can be considered a control site in the shadscale vegetation since it is some distance from any site of planned activity. WS-4 near Ignatio Stage Stop can be used as a site to monitor changes due to vehicular traffic during construction and processing.

Control treatment designations cannot be given to the riparian transects. The river's importance is due to the refuge effects for vertebrates throughout the tract. Paired transects allow for comparisons within and among vegetation types (the same applies to the small live-trapping grids).

Data recorded within a transect's length are: species identification; flushing distance perpendicular to the transect line; number observed; age and sex, where possible; and activity (e.g., feeding, flying). Morning transects are walked for birds, evening transects for mammals.

Eight locations are being sampled during each transect sample period. Each location is sampled for five consecutive days. Four vegetation types are represented by the eight locations. The distribution of sampling effort is shown in Table 17.

Small live-trap grids are used to monitor small nocturnal rodent populations. The grids are set to straddle each of the eight flushing transects. Each grid consists of 25 Sherman live-traps placed 15 m apart covering a 0.36 hectare area. Traps are opened and baited with rolled oats each evening then checked every morning. Each animal captured is identified as to species, age, sex, and sexual and physical condition. Each animal is then weighed and individually marked prior to release.

Live-trapping with the small (5 x 5) grids was conducted during the February and April sample periods and is planned for the work in June and August. Trap grids are set out and operated for five consecutive trap nights during each sample period (See Table 17). All four vegetation types are sampled since small grids straddle the flushing transects.

Table 17

DISTRIBUTION OF FLUSHING TRANSECT EFFORT BY VEGETATION TYPE

Vegetation Type	No. of Transects	No. of Days	Transect Days
Juniper	2	5	10
Greasewood	2	5	10
Riparian	2	5	10
Shadscale	2	5	10

Large live-trap grids will be employed in August to monitor small nocturnal rodents. A 12 x 12 live-trap grid covering 2.7 hectares will be set out in each of the four vegetation associations occurring on the lease tract; shadscale (WS-1), greasewood (WG-1), juniper (WJ-1) and riparian (WR-1). Data collected for each capture will be the same as data recorded for rodents captured in the small live-trap grids. Large live-trap grids will be used in August. A 12 x 12 live-trap grid is operated for five consecutive nights in each of the four major vegetation types (i.e., Juniper, Greasewood, Shadscale and Riparian).

A large mammal aerial survey was planned for two days in December 1976 (see Work Plan). The lack of snow cover and the unusually mild temperatures prevented this work from being carried out.

4.3.2.3 Results to Date. In the February sampling period, twenty-two species of birds were observed on the tracts (Table 18). The weather during this period was warm. Dark-eyed junco and horned lark abundance were notably low. Red-tailed hawks overwintered for the first time in three years of monitoring. Few rough-legged hawks, which are usually abundant north of the tracts, were seen.* It appeared that the mildness of the winter did not necessitate the latitudinal and altitudinal migrations common to the past two winters.

In April 1977, the birds on the tracts increased to 59 species (Table 18). Mating, nesting, and in some cases feeding of the nestling, were well under way. For the first time, sand hill cranes were observed

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* Two previously observed winter residents, the bushtit and the tree sparrow, were absent this period.

Table 18

	HABITAT DISTRIBUTION FEBRUARY 1977 Abundance No. Observed on Transect				HABITAT DISTRIBUTION APRIL 1977 Abundance No. Observed on Transect			
ORDER/SPECIES	Greasewood	Juniper	Shadscale	Riparian	Greasewood	Juniper	Shadscale	Ripar
Ciconiiformes								
Great Blue Heron	-	-	-	-	-	-	-	X
Anseriformes								
Canada Goose	-	-	14	X	-	-	-	15
Mallard	-	-	-	-	-	-	-	4
Green-winged Teal	-	-	-	-	-	-	-	8
Blue-winged Teal	-	-	-	-	-	-	-	2
Common Merganser	-	-	-	1	-	-	-	-
			14	1				29
Falconiformes								
Turkey Vulture	-	-	-	-	-	-	X	1
Goshawk	-	1	-	2	-	-	-	-
Sharp-shinned Hawk	X	X	-	-	-	-	-	-
Cooper's Hawk	-	-	-	-	-	-	-	X
Red-tailed Hawk	X	X	X	8	X	X	2	-
Golden Eagle	3	X	X	-	2	X	X	X
Bald Eagle	-	-	-	X	-	-	-	-
Marsh Hawk	-	-	-	-	X	-	-	-
Prairie Falcon	-	-	X	X	-	X	-	-
Kestrel	-	-	-	-	1	1	2	6
	3	1		10	3	1	4	7

X = Observed in the vegetation type, but not on the transects.

Table 18 (cont'd)

ORDER/SPECIES	HABITAT DISTRIBUTION FEBRUARY 1977 Abundance No. Observed on Transect				HABITAT DISTRIBUTION APRIL 1977 Abundance No. Observed on Transect			
	Greasewood	Juniper	Shadscale	Riparian	Greasewood	Juniper	Shadscale	Ripari
Gruiformes								
Sandhill Crane	-	-	-	-	-	-	-	2
Charadriiformes								
Killdeer	-	-	-	-	-	-	-	X
Greater Yellowlegs	-	-	-	-	-	-	-	X
Columbiformes								
Mourning Dove	-	-	-	-	X	-	X	12
Strigiformes								
Great Horned Owl	X	X	-	2	-	X	-	1
Apodiformes								
White-throated Swift	-	-	-	-	-	-	-	X
Coraciiformes								
Belted Kingfisher	-	-	-	-	-	-	-	2
Piciformes								
Common Flicker	1	X	-	2	4	13	1	28
Hairy Woodpecker	-	-	-	2	-	-	-	5
Downy Woodpecker	-	-	-	3	-	-	-	8
	1			7	4	13	1	41

Table 18 (cont'd)

ORDER/SPECIES	HABITAT DISTRIBUTION FEBRUARY 1977 Abundance No. Observed on Transect				HABITAT DISTRIBUTION APRIL 1977 Abundance No. Observed on Transect			
	Greasewood	Juniper	Shadscale	Riparian	Greasewood	Juniper	Shadscale	Ripar
Passeriformes								
Say's Phoebe	-	-	-	-	3	X	6	5
Willow Flycatcher	-	-	-	-	-	-	-	1
Horned Lark	-	-	10	-	-	-	X	-
Scrub Jay	-	-	-	-	-	-	-	1
Black-billed Magpie	14	1	X	8	11	X	1	13
Common Raven	4	3	X	2	-	-	-	-
Common Crow	-	-	-	-	-	-	-	X
Pinon Jay	-	X	-	-	X	43	-	-
Black-capped Chickadee	-	-	-	3	-	-	-	2
Plain Titmouse	1	X	-	-	1	5	-	-
Bewick's Wren	-	-	-	-	-	1	-	-
Canon Wren	X	X	-	X	-	-	-	X
Rock Wren	-	-	-	-	7	3	5	4
Sage Thrasher	-	-	-	-	X	X	1	-
Robin	-	-	-	-	-	7	-	24
Western Bluebird	-	-	-	-	-	-	-	4
Mountain Bluebird	X	-	-	X	1	4	X	10
Townsend's Solitaire	-	-	-	-	X	X	-	12
Blue-gray Gnatcatcher	-	-	-	-	-	-	-	4
Ruby-crowned Kinglet	-	-	-	-	-	-	-	X
Loggerhead Shrike	X	X	-	-	1	X	5	-
Starling	-	-	-	-	-	-	-	28
Orange-crowned Warbler	-	-	-	-	-	-	-	1
Yellow-rumped Warbler	-	-	-	-	-	-	-	5
Black-throated Gray Warbler	-	-	-	-	-	-	-	1
Western Meadow Lark	-	-	-	-	X	-	18	8
Red-winged Blackbird	-	-	-	-	-	-	-	1
Brewer's Black Bird	-	-	-	-	-	-	-	X
Brown-headed Cowbird	-	-	-	-	-	-	X	-
House Finch	-	-	-	-	-	-	-	63

Table 18 (cont'd)

ORDER/SPECIES	HABITAT DISTRIBUTION FEBRUARY 1977 Abundance No. Observed on Transect				HABITAT DISTRIBUTION APRIL 1977 Abundance No. Observed on Transect			
	Greasewood	Juniper	Shadscale	Riparian	Greasewood	Juniper	Shadscale	Rip
Passeriformes (cont'd)								
Gray-crowned Rosy Finch Black Rosy Finch	X	120	-	-	-	-	-	
Rufous-sided Towhee	-	-	-	-	-	-	-	
Vesper Sparrow	-	-	-	-	X	-	X	
Black-throated Sparrow	-	-	-	-	2	-	-	
Sage Sparrow	-	-	-	-	X	-	17	
Dark-eyed Junco	-	X	-	19	-	11	-	
Gray-headed Junco	-	-	-	-	1	1	-	
Brewer's Sparrow	-	-	-	-	X	-	2	
White-crowned Sparrow	-	-	-	-	-	-	X	
	19	124	10	32	27	75	55	2
Falconiformes								
Falconidae	-	-	-	-	-	2	-	
Strigiformes								
Strigidae	-	1	-	-	-	-	-	
Passeriformes	-	-	-	-	1	-	-	
Parulidae	-	-	-	-	-	-	-	
Icteridae	-	-	-	-	-	-	-	
Fringillidae	-	-	-	-	4	1	-	
Junco sp.	-	-	-	-	-	-	-	
		1			5	3		

Table 19

ORDER/SPECIES	HABITAT DISTRIBUTION FEBRUARY 1977 Abundance No. Observed on Transect or Captured				HABITAT DISTRIBUTION APRIL 1977 Abundance No. Observed on Transect or Captured			
	Greasewood	Juniper	Shadscale	Riparian	Greasewood	Juniper	Shadscale	Ripar
Chiroptera	-	-	-	-	X	-	-	-
Lagamorpha								
Desert Cottontail	41	21	23	12	13	34	22	46
Rodentia								
Eutamias (Chipmunk) sp.	-	-	-	-	-	-	-	-
White-tailed Antelope Squirrel	1	-	2	-	X	X	X	-
Golden-mantled Squirrel	-	-	-	-	X	-	-	X
White-tailed Prairie Dog	-	-	-	-	-	-	X	-
Apache Pocket Mouse	-	-	-	-	1	-	3	-
Ord's Kangaroo Rat	4	-	2	-	5	-	2	-
Beaver	-	-	-	7	-	-	-	1
Western Harvest Mouse	1	-	-	-	-	-	1	2
Canon Mouse	-	1	-	-	-	1	-	-
Deer Mouse	5	-	8	14	11	5	9	16
Pinon Mouse	-	-	-	1	-	-	-	-
Desert Woodrat	1	2	-	-	1	5	-	-
Bushytailed Woodrat	-	3	1	-	6	2	-	-
Muskrat	-	-	-	-	-	-	-	-
Porcupine	-	-	-	10	-	-	-	11
Carnivora								
Coyote	X	X	X	X	X	X	X	X
Striped Skunk	-	-	-	?	-	-	-	-
Artiodactyla								
Mule Deer	X	6	5	X	X	2	3	3
Domestic Sheep	X	X	X	105	X	X	261	X

X = Observed in the vegetation type, but not on the transects.

on the tracts. The most notable increase in abundance occurred in the common flicker. The most notable decrease occurred in the red-tailed hawk. The early nesting again appeared to be in response to the mild and dry weather conditions.

Rodent activity during February was low, showing a slight increase in April (Table 19). The most active rodents in February were Ord's kangaroo rat, the deer mouse and white-tailed antelope squirrels. In April the woodrats and pocket mice were also active. Mule deer activity appeared the same during both periods, with a movement back to the riparian habitat in April. Rabbit abundance showed a slight increase from February to April, plus a shift in activity from the greasewood to the riparian (Table 19).

4.3.3 Aquatic Biology

WRSP is not conducting any aquatic studies during the suspension period. WRSP is, however, following the progress of ongoing USGS work and will incorporate program results into the suspension period's reports as information is made available.

The following discussion, therefore, refers to USGS efforts. The data presented is as yet unpublished by the USGS and subject to revision.

4.3.3.1 USGS Program Status

The aquatic biological program as originally proposed (see Work Plan) has undergone a number of major changes. The sampling frequency has been reduced from monthly to bimonthly to accommodate a reduction in funds and because of observed repetition of data. The Phytoplankton segment has been dropped. One station (09306430; Evacuation Creek at Watson, Utah) has been deleted. Although many changes have occurred in the program, the USGS believes sufficient data will be collected to enable investigators to help establish aquatic environmental controls.

Benthic Invertebrates, Periphyton, and Bacteria are the parameters currently being sampled. Benthic Invertebrates sampling procedure includes four surber samples taken at each site. The organisms collected are then placed in containers and sent to the lab for analysis. As of now, data is not yet available on Benthic Invertebrates.

Because of vandalism and rapidly dropping water levels, Periphyton data is also not currently available. Samplers have disappeared from White River at the mouth, Willow Creek at the mouth, and White River below Asphalt Wash. Other samplers have been found on dry ground due to dropping water levels. A sturdier sampler is being designed so that it might withstand flash floods and maintain greater stability in the water.

Good results have been obtained in the bacteriological portion of the program. The groups sampled are Total Coliforms, Fecal Coliforms, and Fecal Streptoccocus. Fecal Coliform and Fecal Streptoccocus ratios (FC/FS) are being calculated. Sufficient samples are being taken, of different volumes, to guarantee that at least 2 samples fall within the given range for each bacterial group sampled. Data for the period July 1976 through April 1977 are compiled in Table 20.

Table 20

Date	Sample Point	Total Coliform	Fecal Coliform	Fecal Strep.	Ratio FC/FS
07-14-76					
	09306420 Evac. Cr. at Watson, Ut.	*B100	20	25	.80
	09306430 Evac. Cr. nr mouth nr Waton, Ut.	20	20	B180	.11
	09306500 White Rv. nr Watson, Ut.	40	30	25	1.2
07-15-66					
	09306800 Bitter Cr. nr Bonanza, Ut.	28	50	60	.83
	09306850 Bitter Cr at mouth nr Bonanza, Ut.	40	20	100	0.2
	09306900 White Rv at mouth nr Ouray, Ut.	B10	0	0	0
	09307900 Hill Cr. nr mouth nr Ouray, Ut.	Dry	-	-	-
	09308000 Willow Cr. nr Ouray, Ut.	20	B15	60	.25
	09308010 Willow Cr. at mouth nr Ouray, Ut.	Dry	-	-	-
08-18-76					
	09306800 Bitter Cr. nr Bonanza, Ut.	0	0	0	-
	09306850 Bitter Cr. at mouth nr Bonanza, Ut.	40	20	60	.33
08-19-76					
	09306900 White Rv. at mouth nr Ouray, Ut.	B10	0	0	0
	09307900 Hill Cr. at mouth nr Ouray, Ut.	Dry	-	-	-
	09308000 Willow Cr. nr Ouray, Ut.	20	B10	60	.17
	09308010 Willow Cr at mouth nr Ouray, Ut.	Dry	-	-	-
08-20-76					
	09306410 Evac. Cr. ab Missouri Cr. nr Dragon	20	B15	60	.25
	09306420 Evac. Cr. at Watson, Ut.	30	44	40	1.1
	09306430 Evac. Cr. nr mouth nr Watson,Ut.	40	50	B240	.21

Table 20 (cont'd)

Date	Sample Point	Total Coliform	Fecal Coliform	Fecal Strep.	Ratio FC/FS
09-23-76					
	09306410				
	Evac. Cr. ab Missouri Cr. nr Dragon	30	20	50	.40
	09306420				
	Evac. Cr. at Watson, Ut.	70	40	60	.67
	09306430				
	Evac. Cr nr mouth nr Watson, Ut.	B200	B100	B500	.20
	09306500				
	White Rv. nr Watson, Ut.	20	25	25	1.0
	09306800				
	Bitter Cr. nr Bonanza, Ut.	B15	B10	B18	.55
09-24-76					
	09306800				
	Bitter Cr. nr Bonanza, Ut.	22	0	50	0
	09306850				
	Bitter Cr. at mouth nr Bonanza, Ut.	40	B1	100	.01
	09306900				
	White Rv at mouth nr Ouray, Ut.	0	0	0	0
	09307900				
	Hill Cr. at mouth nr Ouray, Ut.	Dry	-	-	-
	09308000				
	Willow Cr. nr Ouray, Ut.	20	B10	80	.12
	09308010				
	Willow Cr. at mouth nr Ouray, Ut.	Dry	-	-	-
12-28-76					
	09306410				
	Evac. Cr. ab Missouri Cr. nr Dragon	0	0	B1	0
	09306420				
	Evac. Cr. at Watson, Ut.	60	30	60	0.5
	09306430				
	Evac. Cr. nr mouth nr Watson, Ut.	0	0	B1	0
12-30-76					
	09306800				
	Bitter Cr. nr Bonanza, Ut.	0	30	B2	15
	09306900				
	White Rv. at mouth nr Ouray, Ut.	0	B5	B1	5
	09307900				
	Hill Cr. nr mouth nr Ouray, Ut.	Dry	-	-	-
	09308000				
	Willow Cr. nr Ouray, Ut.	0	B1	B4	.25
	09308010				
	Willow Cr. at mouth nr Ouray, Ut.	0	0	B10	0

Table 20 (cont'd)

Date	Sample Point	Total Coliform	Fecal Coliform	Fecal Strep.	Ratio FC/FS
02-15-77					
	09306395 White Rv. nr Colorado-Utah State Line	B62	–	40	0
	09306410 Evac. Cr. ab Missouri nr Dragon, Ut	30	0	B12	0
	09306420 Evac. Cr. at Watson, Ut.	40	0	87	0
	09306430 Evac. Cr. nr mouth nr Watson, Ut.	0	0	0	0
02-16-77					
	09306800 Bitter Cr. nr Bonanza, Ut.	B10	40	0	0
	09306850 Bitter Cr. at mouth nr Bonanza, Ut.	46	60	30	2
	09306900 White Rv. at mouth nr Ouray, Ut.	0	0	0	0
04-25-77					
	09306395 White Rv nr Colorado-Utah State Line	50	30	40	.75
	09306410 Evac. Cr. ab Missouri Cr. nr Dragon,Ut	40	0	20	0
	09306430 Evac. Cr. nr mouth nr Watson, Ut.	B150	80	B300	.27
	09306700 White Rv bl Asphalt Wash nr Watson	20	B10	30	.33
04-26-77					
	09306800 Bitter Cr. nr Bonanza, Ut.	B10	0	0	0
	09306850 Bitter Cr. at mouth nr Bonanza, Ut.	20	B10	60	–
	09306900 White Rv at mouth nr Ouray, Ut.	0	0	B3	.33
04-27-77					
	09307900 Hill Cr. at the mouth nr Ouray, Ut.	B10	0	B15	0
	09308000 Willow Cr. nr Ouray, Ut.	30	B15	60	.25
	09308010 Willow Cr. at mouth nr Ouray, Ut.	B15	30	B15	2.0

Section 5.0

REVEGETATION RESEARCH PROGRAM

No one has yet demonstrated vegetation techniques in regard to processed Utah oil shale. Work to date has been confined to Colorado oil shale. WRSP, therefore, initiated a research program in 1975 to develop a technique for the revegetation of processed oil shale on Tract Ua/Ub.

In 1975 the Range Science Department of Utah State University was placed under contract to investigate revegetation of processed shale as well as the rehabilitation of disturbed sites. Dr. C. M. McKell is the principal investigator. The work is expected to be completed by December 1978.

5.1 OBJECTIVES

The objective of this research is to develop a technology utilizing native plant species for revegetating disturbed sites and processed shale disposal area.

5.2 RESEARCH APPROACH

The scientific approach proposed in the revegetation study is based on several important facts or conditions:

1. Plants used in rehabilitating disturbed areas and processed shale disposal sites must be adapted to and persist under the existing environmental conditions.
2. Water is a scarce resource in the oil shale area and any use of it for revegetation must be minimal.

3. Salinity is a serious problem of the processed shale, not only from the aspect of plant establishment and persistence in soils of high salinity but also from the aspect of avoiding saline leachates into the Colorado River system.
4. Surface dust will be a problem in some areas and must be settled or kept minimal.
5. Revegetation of salt desert ecosystems with exotic grass species in previous work has not been successful.

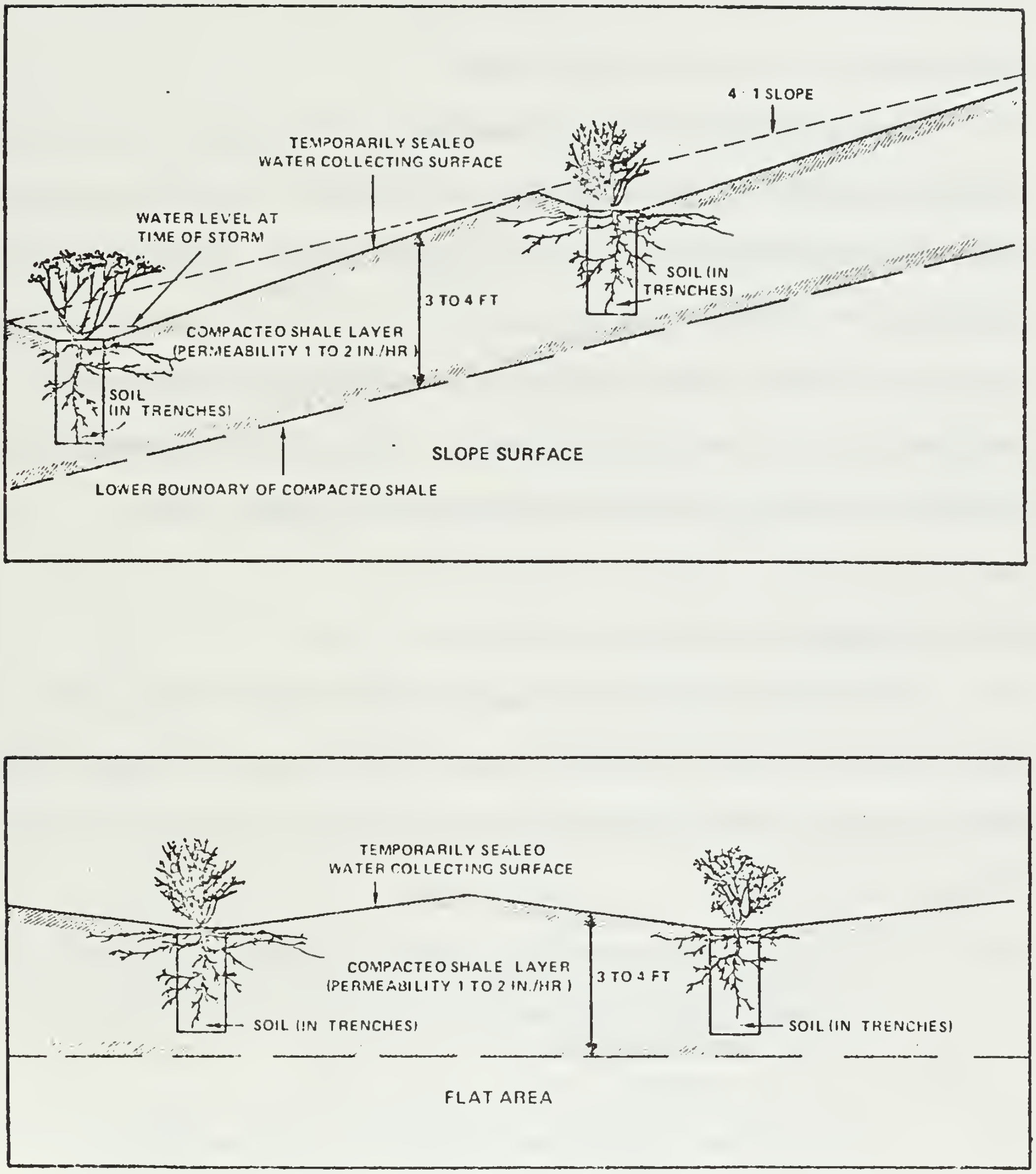
The various strategies proposed for revegetation of disturbed sites and processed shale deposal areas must take into account the above conditions. Native species of the immediate area, particularly shrubs, are being studied for the best means of propagation or planting either by seed or rooting of cuttings. Soil surface sealing materials are under study for their ability to collect water and shed it onto areas where plants have been transplanted, thus not only reducing the requirement for irrigation but also stabilizing surface particles and reducing dust. Salinity problems can be minimized by the use of salinity-tolerant native shrubs such as saltbush (*Atriplex*) and greasewood (*Sarcobatus*).

In addition, minimal irrigation, if necessary, should not be applied to the extent that it would leach salts into the hydrologic system. Transplanted species will be placed in trenches or "post holes" filled with topsoil, thus minimizing the need for expensive stockpiling of topsoil. Diagramatically, the revegetation system would appear as in Figure 27, either for slopes or flat areas.

Water from collected rainfall will irrigate the volume of topsoil and leach salts down and out as it moves through the soil column. Size of basin or collecting area would be made appropriate to the calculated

Figure 27

SURFACE MODIFICATION AND VEGETATION ON PROCESSED SHALE (CONCEPTUAL - NOT TO SCALE)



water needs of the plant and the leaching requirements set up by the soil column.

As the soil surface treatment breaks down over time, annual and perennial plants are expected to colonize the area immediately around the planted shrubs/grasses and gradually cover the soil surface. The transplanted species will provide a major source of seed for subsequent revegetation of the disturbed areas.

The foregoing process draws, as much as possible, upon research already reported in the literature or underway in various locations. Much of the previous work is inadequate, however, to deal with the problems presented by the spent shale or the salt desert ecosystem of the Ua/Ub region. Some innovation in combining the results of previous work and some new research is needed. None of the research being done by WRSP will duplicate that which has already been done.

5.3 RESULTS

The study progress and results determined through June 30, 1976 have been previously published in Quarterly Baseline Reports and more specifically in the following documents (both of which have been delivered to the AOSS):

1. "Third Progress Report (1/1/76 - 6/30/76) Revegetation Studies for Disturbed Areas and Processed Shale Disposal Sites" by Utah State University, (Dr. C. M. McKell principal investigator).
2. "Achieving Effective Revegetation of Disposed Processed Oil Shale: A Program Emphasizing Natural Methods in an Arid Environment." May 1976: Land Rehabilitation Series No. 1, Agricultural Experimental Station, Utah State University (Dr. C. M. McKell).

The following paragraphs discuss the highlights of the work accomplished from July 1, 1976 to December 31, 1976. The full text of the report for this period can be found in Appendix A.

Following a relatively average spring growing season, the summer and fall of 1976 were difficult for field research. The summer was hot and dry and the fall was much drier than usual. These conditions were especially critical for survival of planted species. In addition, the long, dry fall appeared to accentuate the need of small mammals for water and green feed, thus turning them to browse on the experimental plantings. Whether severely browsed seedlings will be able to survive remains to be seen.

Considerable research effort has been directed toward development of suitable techniques for propagating native species, particularly shrubs. Improved sagebrush propagation and better selection of cuttings of shrubs are possible as a result of our in-depth studies. Sagebrush roots are best when cuttings are obtained from dormant plants and higher than usual hormone levels are applied. Cuttings of female plants of _Atriplex_ appear to root better than male plants. Work is underway to prepare a manual on propagation of several native plant species of the oil shale region useful for revegetation.

Shrub seedling growth and survival in shale is improved by the addition of fertilizer elements, such as Nitrogen and Phosphorus. Addition of sulfuric acid to reduce the pH appears to increase the salinity because of the liberation of positive ions, especially Ca^{++}.

Cheatgrass and Russian Thistle Germination. A unique study reported in the present progress report (Appendix A) deals with the tolerances of cheatgrass (Bromus tectorum) and Russian thistle (Salsola kali). Seeds of these two weedy invaders are sometimes present in great abundance in the area of the processed oil shale disposal site and would, thus, be prime invaders and colonizers of revegetated areas. Our studies show that both species have a relatively wide range of tolerance for the moisture and salinity stresses present in a shale area. It appears that they would probably invade open areas after processed shale deposition. These species may prove valuable for early stabilization of disturbed areas and disposal sites in spite of their bad reputation as weeds. At least we have information that can help in a control program.

The work reported in the full report (Appendix A) represents a sizable effort in eight study sites over Tract Ua/Ub. Results indicate satisfactory establishment and persistence in the face of difficult environmental conditions. The long, dry fall has been especially difficult. One more assessment in the spring of 1977 and we will be ready to prepare a manuscript on our results of this important study.

Three replications of treatments on Paraho processed shale columns have produced an interesting pattern of salinity reduction with increasing amounts of added water. The first half liter of leachate passing through a 90-cm long column of shale had an electrical conductivity (EC) of about 35. By the end of the leaching cycle in which 15 liters had passed through, the shale, the EC of the leachate was 3 mmhos/cc. Further tests on specific ions in the leachate are underway.

Water harvesting studies were initiated in the late summer and fall of 1976. Small basins, 75 cm in diameter, treated with a polyvinyl acetate material to stabilize the soil surface were twice as effective in collecting water as those with a non-treated soil surface. Polyvinyl acetate materials are receiving further study during the winter and spring period for durability and effectiveness.

A pilot model of a processed oil shale disposal pile was constructed during the summer and early fall at the research site in Section 6 near Bonanza, Utah. Preliminary studies of water and salinity movement, plant growth, and leachate salt concentration will be possible during 1977 and 1978. A follow-up research proposal to ERDA has been prepared along lines of investigation initiated with the pilot model.

Limited Use Document: Findings and conclusions written in this report are provisional and subject to final review. Data may not be cited until published in regular channels.

FOURTH PROGRESS REPORT

1 July 1976 to 31 December 1976

REVEGETATION STUDIES FOR DISTURBED AREAS AND PROCESSED SHALE DISPOSAL SITES

Submitted by
Utah State University
Institute for Land Rehabilitation[1]

To
White River Shale Project

Emphasizing Federal Oil Shale Prototype
Leasing Program Requirements, Utah Tracts Ua, Ub

Prepared By: C. M. McKell, Professor of Range Science
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[1] The Institute for Land Rehabilitation is sponsored by the Agricultural Experiment Station and the College of Natural Resources.

REVEGETATION STUDIES FOR DISTURBED AREAS AND PROCESSED SHALE DISPOSAL SITES

FOURTH PROGRESS REPORT

RESEARCH ON REVEGETATION OF
PROCESSED OIL SHALE AND DISTURBED SITES
PROJECTS UNDERWAY-
- Pilot Model of Shale Disposal Pile
- Surface Stabilizers
- Season and Method of Planting Shrubs and Grasses
- Plant Growth in Shale/Soil
- Water Harvesting Studies
- Root Growth of Container Grown Shrubs
- Effects of Pruning on Transplant Growth
- Revegetation Plant Demonstration
UTAH STATE UNIVERSITY INSTITUTE FOR LAND REHABILITATION
on contract to
WHITE RIVER SHALE PROJECT

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I. HIGHLIGHTS OF SIX-MONTH REPORT

A. An Overview of the Period July-December, 1976

Following a relatively average spring growing season, the summer and fall of 1976 were difficult for field research. The summer was hot and dry and the fall was much drier than usual. These conditions were especially critical for survival of planted species. In addition, the long, dry fall appeared to accentuate the need of small mammals for water and green feed, thus turning them to browse on the experimental plantings. Whether severely browsed seedlings will be able to survive remains to be seen.

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Considerable research effort has been directed toward development of suitable techniques for propagating native species, particularly shrubs. Improved sagebrush propagation and better selection of cuttings of shrubs are possible as a result of our in-depth studies. Sagebrush roots best when cuttings are obtained from dormant plants and higher than usual hormone levels are applied. Cuttings of female plants of *Atriplex* appear to root better than male plants. Work is underway to prepare a manual on propagation of several native plant species of the oil shale region useful for revegetation.

C. Shrub Seedling Growth and Survival

Shrub seedling growth and survival in shale is improved by the addition of fertilizer elements, such as Nitrogen and Phosphorus. Addition of sulfuric acid to reduce the pH appears to increase the salinity because of the liberation of positive ions, especially Ca^{++}.

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A unique study reported in the present progress report deals with the tolerances of cheatgrass (*Bromus tectorum*) and Russian thistle (*Salsola kali*). Seeds of these two weedy invaders are sometimes present in great abundance in the area of the processed oil shale disposal site and would, thus, be prime invaders and colonizers of revegetated areas. Our studies show that both species have a relatively wide range of tolernace for the moisture and salinity stresses present in a shale area. It appears that they would probably invade open areas after processed shale deposition. These species may prove valuable for early stabilization of disturbed areas and disposal sites in spite of their bad reputation as weeds. At least we have information that can help in a control program.

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Three replications of treatments on Paraho processed shale columns have produced an interesting pattern of salinity reduction with increasing amounts of added water. The first half liter of leachate passing through a 90-cm long column of shale had an electrical conductivity (EC) of about

35. By the end of the leaching cycle in which 15 liters had passed through, the shale, the EC of the leachate was 3 mmhos/cc. Further tests on specific ions in the leachate are underway.

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Water harvesting studies were initiated in the late summer and fall. Small basins, 75 cm in diameter, treated with a polyvinyl acetate material to stabilize the soil surface were twice as effective in collecting water as those with a non-treated soil surface. Polyvinyl acetate materials are receiving further study during the winter and spring period for durability and effectiveness.

H. A pilot model of a processed oil shale disposal pile was constructed during the summer and early fall at the research site in section 6 near Bonanza, Utah. Preliminary studies of water and salinity movement, plant growth, and leachate salt concentration will be possible during 1977 and 1978. A follow-up research proposal to ERDA has been prepared along lines of investigation initiated with the pilot model.

II. INTRODUCTION

Research on problems associated with establishment of vegetation on disturbed sites and processed oil shale took on several new dimensions with the availability of processed shale for field and laboratory research. Greenhouse-laboratory studies of plant growth on processed shale were carried out and new studies are planned on the basis of what has been learned. A pilot model of an oil shale disposal pile was established in the Section 6 study area utilizing Utah shale processed by the Paraho and the Union Oil Co. processes. We also conducted some leaching studies utilizing 90 cm columns of processed shale in which the decreasing concentration of salts in successive increments of leachate was observed.

The year 1976 was unique in many respects, but in comparison with 1975, the conditions for plant growth were difference and generally more difficult. From the standpoint of plant survival, the long, dry fall period was especially critical. Many of the transplants that were planted in the fall of 1975 and the spring of 1976 were doing well until the long, dry fall occurred. We believe the normal survival percent was reduced both by drought and rodent damage. The rodent damage was accentuated by the shortage of water which caused them to eat any green plant material for the water it contained.

Research by graduate students working on thesis problems related to oil shale rehabilitation added considerable strength to the present report and to accumulating knowledge base for rehabilitation of disturbed lands.

We look forward to the completion of at least two M.S. theses in June and another in September.

We have revised a proposal prepared earlier for study of problems related to the movement of salts through a disposed processed shale pile and the attending phenomena of nitrogen cycling, plant growth and water relations. Other opportunities for additional funding are under constant review.

III. LITERATURE REVIEWS

In our previous six-month report we indicated a possible opportunity for receiving a contract to do a literature review on a land rehabilitation subject. In late July we contracted with the U.S. Fish and Wildlife Service, Western Energy and Land Use Team, to do a state-of-the-art summary, an annotated bibliography, a survey of current research projects in land rehabilitation and a field handbook. Drafts of all of the documents have been prepared and are in the early review and revision stages. Work on this literature review project will enhance our capability for rehabilitation research in general and provide visibility for the Institute for Land Rehabilitation. Further, the publication of the review containing our interpretations and point of view should prove useful in a general way for the rehabilitation of disturbed lands. For the research on oil shale problems, we have had considerable assistance in looking at the broad problems of providing wildlife habitat requirements.

IV. PROPAGATION OF NATIVE SPECIES

A. Vegetative Propagation of *Atriplex, Chrysothamnus* and *Grayia*.

In a continuation of previous efforts to identify problems that might exist in the vegetative propagation of native shrubs ecologically dominant and important in the arid oil shale region of eastern Utah, we have initiated a concentrated study to find suitable methods of asexually propagating several important species. A careful review of our past efforts dealing with those species resulted in the compilation of a listing of the most useful shrubs, forbs and grasses. Throughout the course of this winter we will make several trips into the field to collect these species and test various methods of asexual propagation, such as season of collection, methods of collection and handling, types of rooting hormones and rooting mediums necessary for successfully rooting. To date, several important parts of this study have been completed and some important results have been obtained. A literature review on each of the species selected for study, the outline and some initial sections have been completed for a "Manual on the Propagation of Native Plants Useful for Revegetation in the Arid Oil Shale Region."

1. Rooting response of completely dioecious plants. To determine if differences in rooting on dioecious plants was influenced by the sex of the plant, an experiment was established with five female and five male plants of *Atriplex canescens* and *A. cuneata*. Cuttings were collected near the section 6 study site and transported to the greenhouse in Logan. Care was taken to ensure that all plants were treated uniformly. A total of 50 cuttings (5 replications of 10 plants each) from each plant

were prepared and planted in Jiffy #9 peat pellets and placed inside a plastic mist chamber in a greenhouse maintained at 75°F and watered daily. Each cutting was approximately 8 cm long and was treated with Hormodin #3 (contains .8% IBA). The terminal tip was removed from each treated stem.

Statistical analysis indicates that sex made no difference in the rootability of *A. canescens* plants but male *A. cuneata* plants were found to root significantly better than female plants (Table 1). Except for the one female *A. canescens* with a high rooting percentage, the males of this species rooted better and more consistently than did the female plants of this species. Virtually every male plant of both species produced some roots but three of the five female fourwing saltbush failed to root and one of the female cuneate saltbush failed to produce any roots. Further study of the influence of sex on rooting and field performance will be undertaken in the spring. Results of this study should provide improved criteria for field planting recommendations.

Table 1. Percent rooting of male and female *Atriplex canescens* and *A. cuneata* plants, six weeks after planting

		Plant					
Species	Sex	1	2	3	4	5	$\bar{X}$
Atca	male	22	20	34	8	10	18.8
	female	76	0	22	0	0	19.6
Atcu	male	26	16	4	8	8	12.4*
	female	0	8	20	2	6	7.2

*significantly difference at the 0.10 level.

2. Rooting of individual female plants of *Atriplex canescens* and *Grayia brandegei*. An experiment was designed to test the influence of different levels of IBA rooting hormone to induce root formation of these two species. Six treatments were employed: control, 1 percent IBA, .3 percent IBA, .6 percent IBA, .8 percent IBA and 2 percent IBA. Fifty cuttings were used for each treatment of *Atriplex* and 21 cuttings were used for each treatment of *Grayia*. At the conclusion of this experiment, six weeks after planting, no rooted plants could be found for either species.

The implications are that when plants fail to respond regularly to root induction, they may not root even under extremely high levels of IBA hormone.

Other factors may be operating and must be clarified before rooting methods can be outlined. As was mentioned in our last semi-annual report, to obtain vegetative propagation of *Artemisia tridentata*, it is necessary to identify those individual plants that are capable of rooting before a widespread pro-ram of vegetative progation is started. A preliminary screening of plants capable of rooting will save alot of time. As results of the *Artemisia tridentata* experiments indicate, it is possible to select individuals that root extremely well even within this difficult-to-root group.

In addition to the differences obtained by comparing different plants, there appears to be strong evidence that different stems on the same plant respond differently to root induction. In both *Atriplex* species evaluated, we found that statistically significant differences could be obtained in the percent rooting. As much as five-fold variation was obtained for the rooting of *Atriplex canescens* and a four-fold variation in rooting was obtained for *A. cuneata*. Evidence obtained in the present study indicates that even though the plant may be a prolific rooter, certain stems on the same plant would produce only meager rootability.

Results from the present study confirm some previous observations in monecious plants; that stems containing female parts always produced cuttings possessing female parts. Male parts produced only male parts. Evidence tends to indicate that certain substances in the stem have more influence over the plant than has been reported previously.

3. Rooting of *Chrysothamnus viscidiflorus* var. *linifolius* and *Sarcobatus vermiculatus*: A third experiment was designed to evaluate the rootability of these two shrubs under conditions mentioned previously. One hundred cuttings of each species were treated with 0.8 percent IBA powder, watered daily and removed to determine rooting after eight weeks. Virtually no rooting could be detected and it was concluded that the peat pellets used as a rooting medium must be maintained at a constant moisture level. The mist chamber was modified and we expect to repeat this experiment in January. Since greasewood has failed to root under a series of conditions, we plan to drop this species from further trials at the present time and rely on seeds for propagation.

B. Rooting of Vegetative Cuttings Collected from Non-Dormant Plants.

In earlier trials (see Third Progress Report--June 30, 1976), cuttings of *Atriplex cuneata*, *A. corrugata*, and *Ceratoides lanata* collected in March and April rooted about 50 percent. *Grayia brandegei* and *G. spinosa* failed to root. Cuttings were collected again in early summer to see if the rooting response at that time might differ from the rooting in early spring and late winter when plants are emerging from dormancy.

Vegetative cuttings of *Atriplex corrugata*, *A. confertifolia*, *A. gardneri*, *A. cuneata*, *A. canescens*, *Ceratoides lanata* and *Grayia brandegei* were collected from northeastern Utah on July 16, 1976. Another collection of *Atriplex cuneata* cuttings was made preciously on June 18. The cuttings were dipped in 0.8 percent IBA powder and placed in moistened peat pellets. The cuttings were examined for rooting after 30 days.

Fifty-one of the 56 *A. cuneata* cuttings collected on June 18 rooted for 91.1 percent. The results of the July 16 collection are shown in Table 2. Rooting of the *Atriplex* species was generally near 90 percent. Rooting of both *Atriplex cuneata* and *A. corrugata* was generally better in July than in April, while the rooting of *Ceratoides lanata* decreased considerably in July. *Grayia brandegei* failed to root in both April and July.

Temperatures were higher (sometimes exceeding 40°C) in the greenhouse rooting chamber in July than in April. It is not presently known whether the differences in rooting between the April and July collections were due to differences in greenhouse temperatures or differences in the physiological status of the plants at the two collection dates. Both factors may have been interacting.

Table 2. Rooting of vegetative cuttings collected July 16, 1976.

Species	Number of Cuttings	Number Rooted	Percent Rooted
Atriplex corrugata	96	88	91.7
Atriplex confertifolia	96	87	90.6
Atriplex gardneri	192	170	88.5
Atriplex cuneata	192	182	94.8
Atriplex cuneata	96	57	59.4
Atriplex canescens	131	122	93.1
Ceratoides lanata	152	8	5.3
Grayia brandegei	192	0	0.0

Cuttings dipped in 0.8 percent IBA powder and placed in moistened Jiffy #9 peat pellets for 30 days.

C. Effect of Sex and Plant Variability on Rooting Response

Many factors affect the rooting responses of various plant species. The following experiment was performed to determine whether the sex of dioecious (having separate sexes) species might affect rooting.

Cuttings were collected on November 23, 1976, from five male and five female plants of both *Atriplex cuneata* and *A. confertifolia*. Fifty-five cuttings from each plant were dipped in 0.3 percent IBA powder and placed in moistened peat pellets. Cuttings were examined for rooting after 30 days in the rooting chamber.

The mean rooting percentage of male *Atriplex cuneata* plants was significantly greater than that of the female plants (Table 3). There was no difference in rooting between male and female *Atriplex confertifolia* plants. The data also show the high variability of rooting between plants. For example, percent rooting of the female *Atriplex confertifolia* plants ranged from 3.6 to 52.7, a range of 49.1.

The results indicate that plant sex and variability between plants can be added to the list of factors affecting rooting of salt desert shrub species.

Table 3. Rooting of *Atriplex cuneata* and *A. confertifolia* as affected by plant sex and plant variability.

Species		Male	Female
Atriplex cuneata		70.9	23.6
		36.4	3.6
		25.5	18.2
		70.9	12.7
		69.1	32.7
	mean	54.6*	18.6
	S.D.	21.9	11.0
Atriplex confertifolia		7.3	52.7
		10.9	12.7
		38.2	29.1
		21.8	3.6
		25.5	29.1
	mean	20.7	25.4
	S.D.	12.3	18.8

*Difference between male and female rooting significant at .05 level by analysis of variance.

S.D. = standard deviation.

Cuttings (55 per plant) dipped in 0.3 percent IBA powder and placed in peat pellets for 30 days.

D. Propagation of Big Sagebrush

This study was established as a thesis project by Mr. Eduardo Alvarez to develop a vegetative propagation methodology for big sagebrush and to test the influence of (1) collection date, (2) growth controlling substance treatment and (3) variability in rootability among plants on the rooting performance of stem cuttings.

The following was utilized:

1. Propagation material: stem cuttings of previous growth season (approximately one year old) with intact terminal buds.
2. Collection procedure: cuttings clipped from plants in the field, placed in slightly moist paper bags and transported in a portable ice-filled chest.
3. Treatments: the basal, 4 cm of all cuttings, were (a) defoliated by hand plucking, (b) dipped in water and then into the indole butyric acid (IBA) talc mixture (control cuttings only dipped in water, and (c) planted by insertion in peat pellet.
4. Rooting environment / Rooting media: expanded peat pellets (Jiffy #9); Rooting chamber: a clear plastic enclosure located on a bench in the southwest corner of a glass house. Cuttings were placed directly on a fine mesh screen 30 cm above the plastic-covered bench; Rooting conditions: the glass house was equipped with steam pipes under the benches, no control of this heating facility was available. Record of daily temperature inside the rooting chamber was kept. High humidity conditions were maintained by daily sprinkling the cuttings with a hose.
5. Duration: cuttings were kept undisturbed inside the rooting chamber for 40 days before assessing results.
6. Data collected: observations of number of days to visual identification of roots in the peat pellets and of phenological development of cuttings. Daily record of temperature of chamber and/or rooting medium. Rooting percentage calculated from the number of rooted cuttings out of planted cuttings.

Two subspecies of *A. tridentata* have been studied with the following results:

a. Subsp. *Vaseyana:* A trial was set up to study rootability differences among individual plants and the effect of basal treatment of the cutting with indole butyric acid (IBA). Since previous attempts to root big sagebrush during the summer months meet with failure or very poor success, dormant cuttings (Quiecent) were collected in the first week of February for this test. Four plants were selected on the field at Green Canyon (northeast of Logan) and one-hundred cuttings collected from each. The cuttings from each plant were divided into groups of twenty assigned to five levels of IBA (control, 0.1, 0.3, 0.8 and 2.0 percent IBA in talc). The results of this experiment are presented in Table 4.

The results of this trial show marked differences in rootability among plants and a definite stimulation of rooting by application of IBA. Figure 1 shows the rooting response curve for each plant and the average for the experiment.

b. Subsp. Based on the results obtained with Subsp. *Vaseyana*, two experiments were set up to study the effect of date of collection on rooting response. In addition, the differences in rootability of plants and three IBA levels were considered for this subspecies of big sagebrush.

The propagation material for this study was collected at the Prototype Oil shale Lease Tracts in the Uintah Basin south of Bonanza, Utah.

Experiment a: Five plants were selected in the field to collect thirty cuttings from each at four dates (5 x 30 x 4 = 600 cuttings). The

Table 4. *A. tridentata* subsp. *vaseyana* collected at Green Canyon northeast of Logan on February 3, 1976. Rooting time: 55 days. Rooting percentage: 20 cuttings/treatment (100 cuttings/plant).

Plant Number	Control 0.0	Hormone Level (% IBA in talc)				Avg. % Rooting for Plants
		0.1	0.3	0.8	2.0	
1	25	40	60	95	90	62
2	40	50	85	75	90	68
3	5	20	20	20	35	20
4	5	0	5	65	80	31
Avg. % Rooting for Treatments	19	27	42	64	74	Avg. % Rooting for all Cuttings 46.25

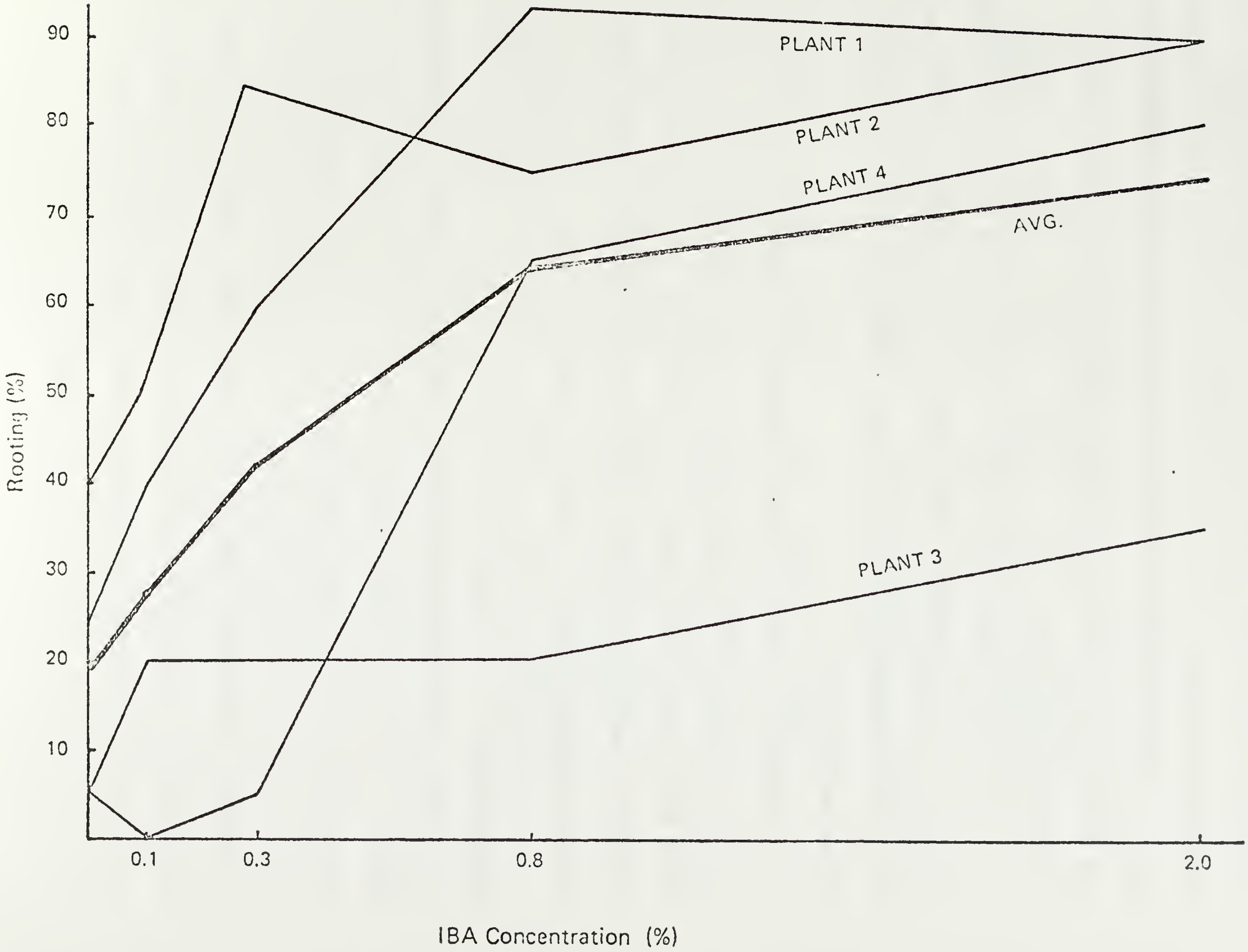

90
80
70
60
50
40
30
20
10
Rooting (%)
0.1
0.3
0.8
2.0
IBA Concentration (%)
PLANT 1
PLANT 2
PLANT 4
AVG.
PLANT 3

FIGURE 1.

collection dates were March 26, 1976, when the plants were in the transition period between dormancy (quiecence) and spring activity and subsequently two weeks apart on April 10, April 24, and May 8, 1976, to cover the period during which approximately half of the seasonal growth is attained in the stems.

All cuttings were treated with 2.0 percent IBA to ensure maximum expression of rootability. The results are presented in Table 5 and the rooting performance of each plant plotted against the collection dates on Figure 2.

The results show a definite decrease in rooting success when the plants reach the period of most active growth after April 24, suggesting that the rootability becomes nill after May 8. This may be due to anatomical and physiological changes in the stem tissue which onset with the normal growth and flowering cycle of this species.

Experiment b: This experiment was carried out simultaneously with Experiment a and consisted of using five intact plants at each collection date. The collection dates were the same as in Experiment a and the plants were used only once at the assigned date. In total, twenty plants were used in this experiment, 90 cuttings collected from each and divided into three IBA levels, control (0.0 percent IBA), low (0.3 percent IBA) and high (2.0 percent IBA). The results of this trial are presented in Table 6 as the average rooting percent of the five replications (5 plants x 30 cuttings) for each treatment.

Table 5. *A. tridentata* subsp. 30 cuttings collected from each of 5 plants at four different dates. Total 120 cuttings/plant. All cuttings treated with 2.0% IBA.

	Collection Date				
Plant Number	I March 26	II April 10	III April 24	IV May 8	% Rooting Average for Plants
1	6.7	0.0	3.3	0.0	2.5
2	96.7	100.0	73.3	33.3	75.8
3	16.7	16.7	3.3	0.0	9.2
4	0.0	10.0	0.0	0.0	2.5
5	33.3	36.7	43.3	0.0	28.3
Average % Rooting for Collection Date	30.7	32.7	24.7	6.7	Average % Rooting for all Cuttings 23.7

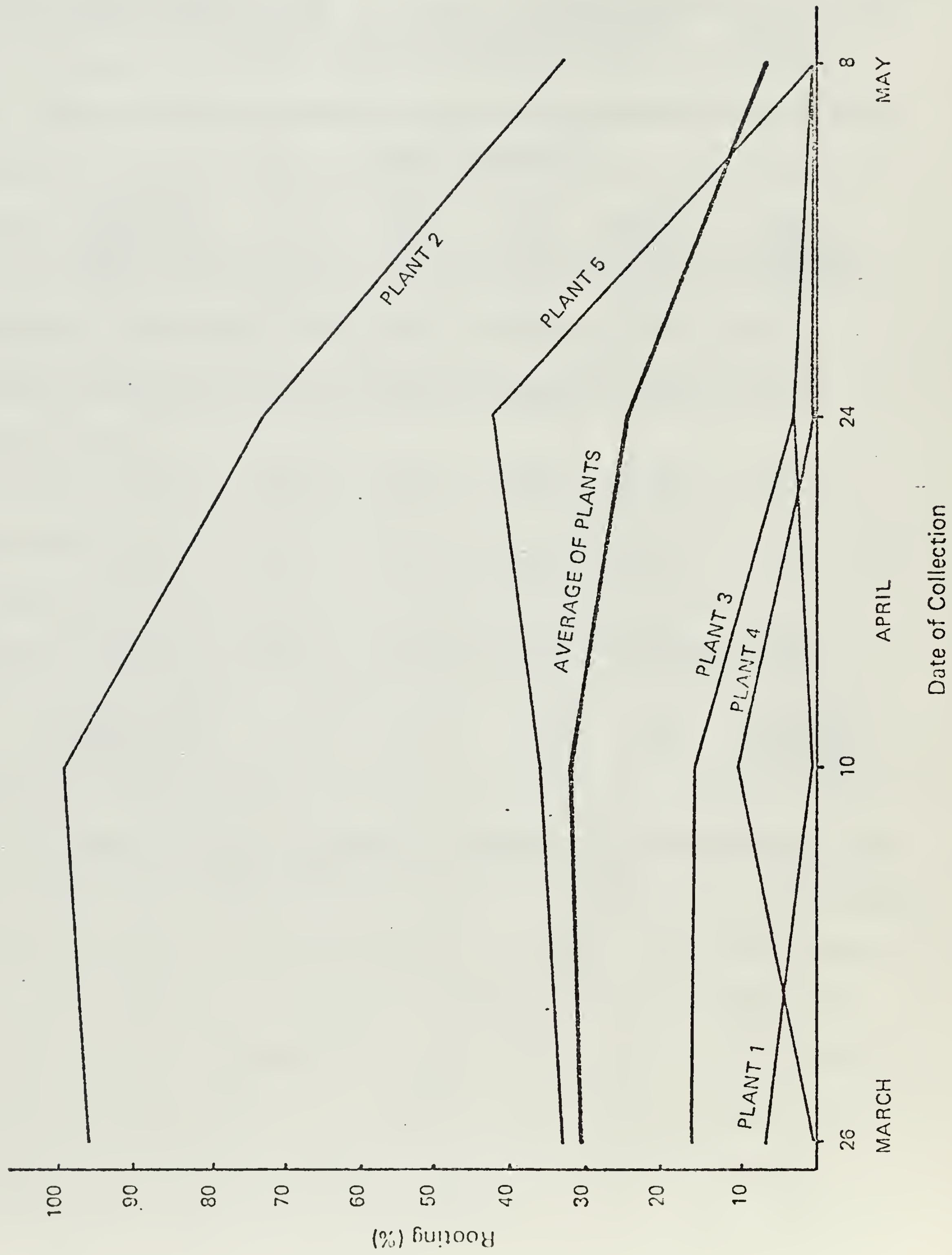

Rooting (%)
100
90
80
70
60
50
40
30
20
10
26
MARCH
10
APRIL
24
8
MAY
Date of Collection
PLANT 2
PLANT 5
AVERAGE OF PLANTS
PLANT 3
PLANT 4
PLANT 1

Table 6. *A. tridentata* subsp. Five different plants used at each date to collect 450 cuttings (5 x 90). The 90 cuttings from each plant divided into the three IBA levels (5 x 30 x 3 = 450 at each date). A total of 1800 cuttings used.

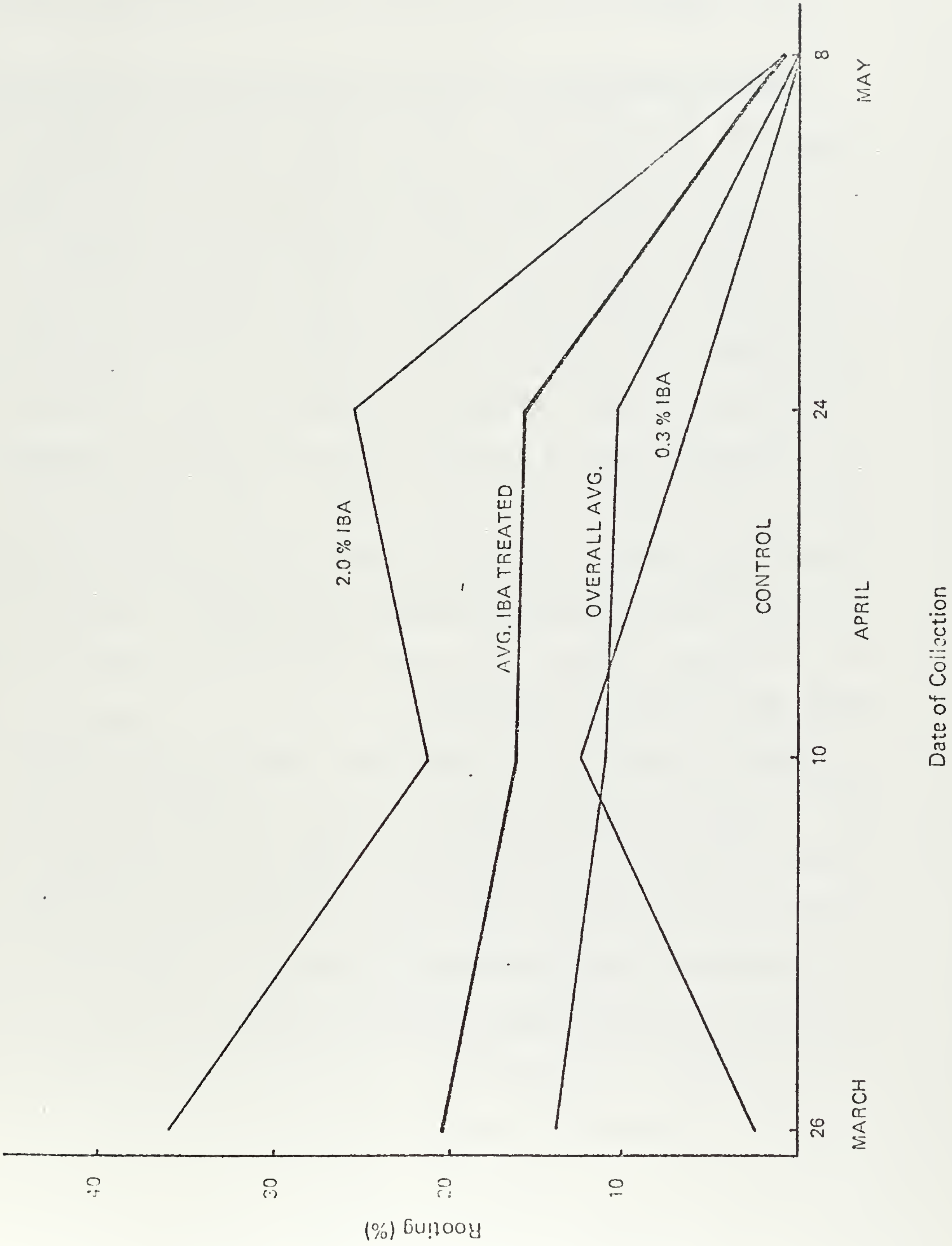
% Rooting Average of 5 plants at each date				
Date	Control 0.0% IBA	Low 0.3% IBA	High 2.0% IBA	Average Rooting Collection Date
I March 26	0.0	4.7	36	13.6
II April 10	0.0	12	21.3	11.1
III April 24	0.0	6.7	25.3	10.7
IV May 8	0.0	0.7	1.3	0.7
Hormone Level Average Rooting	0.0	6.0	21.0	

Figure 3 shows the rooting response in time for each IBA level and the average rooting curve for the treated cutting and for all cuttings in this experiment. In this trial no roots were observed on control (untreated) cuttings suggesting a need for the IBA treatment if success is to be attained with non-dormant cuttings.

The rootability of the plants shows the same tendency as in Experiment a to sharply decline after the 24th of April with the increasing growth activity in the plants.

The information collected on big sagebrush indicates that there are good and poor rooting plants in the field which need to be identified when propagating the species, at the moment the only method available is the actual testing of cuttings. Treatment with IBA is necessary to root non-dormant cuttings, the higher level of IBA applied (2.0 percent) gave the most favorable results. The collection of cuttings should preferably be before the end of April since after that date the rooting ability drops sharply.

These results are currently being processed into a document to fulfill the thesis requirement for the Masters program and will also be published.


Rooting (%)
40
30
20
10
2.0 % IBA
AVG. IBA TREATED
OVERALL AVG.
0.3 % IBA
CONTROL
26
MARCH
10
APRIL
24
8
MAY
Date of Collection

V. EFFECT OF CONTAINER SIZE AND SHAPE ON FIELD PERFORMANCE OF THREE NATIVE SHRUBS.

Research continues on the effect of container size and shape on root growth of native shrubs. Every two weeks during the months of July, August, September and October of 1976 soil psychrometer readings, plant height and plant survival data were obtained. As reported in the previous six-month report, the data will be used in evaluating the hypothesis that container size and shape will not inhibit root growth after the plants have been transplanted to the field. The data obtained thus far is currently under going statistical analysis to see if any significant trends are present. Heavy predation on the plants by rabbits and rodents will make the survival and plant height data difficult to relate to container-caused problems. However, the soil psychrometer data are complete and should give some good results to be used in testing the hypothesis.

Starting in March of 1977 psychrometer readings, plant height and plant survival data will be obtained every two weeks until June or July. At the end of this period the plants will be harvested to examine the root system of each plant. The harvested root systems will be compared to root systems of wildlings of the same species to see if any gross morophological differences occur which were caused by the container.

VI. PHYSIOLOGICAL STUDIES OF PLANT GROWTH IN PROCESSED SHALE.

A. Growth of *Atriplex cuneata* and *A. gardneri* in Processed Oil Shale as Affected by Various Forms of Nitrogen Fertilizer.

In previous experiments (see Third Progress Report--June 30, 1976) the growth and survival of some salt desert shrub species on highly alkaline or highly saline processed oil shale samples were better when plants were fertilized with nitrate nitrogen than when fertilized with ammonium nitrogen. The following experiment was performed to compare the growth responses of two salt desert shrub species to several forms of N fertilizer on a moderately saline, moderately alkaline sample of processed oil shale.

Cottage cheese tubs (24 oz. size) were filled with 700 grams of air dry, quarter-inch-screened paraho processed Colorado oil shale sample #2 (see Third Progress Report for chemical properties). Phosphorus as NaH_2PO_4 was added to each pot at the rate of 46 ppm. Nitrogen was applie at the rate of 40 ppm as either urea $(NH_4)_2SO_4$, NH_4Cl, $NaNO_3$ or $Ca(NO_3)_2$. An additional treatment of 80 ppm N as $Ca(NO_3)_2$ was also included. Rooted cuttings of *Atriplex cuneata* and *A. gardneri* were then planted in the fertilized shale. Distilled water was added by weight daily to maintain a soil moisture percentage of 23.5. There were 5 replications of each fertilizer treatment per species. Shoots were harvested 60 days after planting, and oven-dry weight were measured.

Table 7 shows the shoot yields of *Atriplex cuneata* and *A. gardneri* grown on processed oil shale treated with various fertilizer treatments. For both species there was a much greater growth response to the nitrate

Table 7. Dry weights of *Atriplex cuneata* and *A. gardneri* plants grown on processed oil shale treated with various forms of N fertilizers.

Fertilizer	ppm N	Dry Weights of Shoots in Grams	
		A. cuneata	*A. gardneri*
urea	40	0.5150a	0.3732a
$(NH_4)_2SO_4$	40	0.3260a	0.2014a
NH_4Cl	40	0.3402a	0.2478a
$NaNO_3$	40	0.9324b	0.8261b
$Ca(NO_3)_2$	40	1.1878c	0.7715b
$Ca(NO_3)_2$	80	1.7834d	1.5622c

means followed by the same letter within each species are not significantly different at the .01 level using Duncan's multiple range test.

form of nitrogen than to ammonium or urea nitrogen. *Atriplex cuneata* responded better to $Ca(NO_3)_2$ than to $NaNO_3$, indicating a possible high calcium requirement for this species. Growth of both species was greater with $Ca(NO_3)_2$ at 80 ppm N than at 40 ppm N.

The results of this experiment and two previous experiments indicate that the nitrate form of nitrogen is more readily used by several salt desert shrub species than urea or ammonium nitrogen. Before urea or ammonium fertilizers can be used effectively by many species they must be converted to nitrate by nitrifying bacteria. Nitrifying bacteria are normally present in most soils but would initially be absent in processed oil shale disposal piles. Over a period of years the shale disposal piles would eventually become innoculated by nitrifying bacteria and by other microorganisms carried on wind-blown soil particles. The innoculation process can be speeded considerably by mixing small amounts of topsoil into the surface layers of the processed shale or by placing soil in trenches as described by McKell (1976)

B. Tolerance of *Atriplex cuneata* to Various Levels of Na_2SO_4 and $MgSO_4$

The predominant salts contributing to the salinity of processed oil shale samples from Utah and Colorado are Na_2SO_4 and $MgSO_4$. Previous experiments (Third Progress Report--June 30, 1976) indicate two *Atriplex* species have high tolerance to Na_2SO_4, but the tolerance of these and species to $MgSO_4$ is unknown. The following experiment was performed to test the salt tolerance of another *Atriplex* species, *Atriplex cuneata*, and to compare responses to $MgSO_4$ and Na_2SO_4.

McKell, C.M. 1976. Achieving effective revegetation of disposed processed oil shale: a program emphasizing natural methods in an arid environment. Agric. Exp. Sta. Land Rehabilitation Series No. 1. 17 pages.

Soil from the vicinity of Bonanza, Utah was mixed half and half with sand. Eighteen hundred grams of the soil-sand mixture were placed in each plastic-lined quart milk carton. Sufficient quantities of Na_2SO_4, $MgSO_4$ or a combination were added to the containers to produce osmotic potentials of 0, -5, -10, -20, or -30 atm at 10 percent soil moisture. The 10 percent soil moisture level was maintained throughout the experiment by daily weighing and watering. Rooted cuttings were planted in the containers and harvested after 90 days of growth. Dry weights were then determined. There were five replications of each salt treatment.

Table 8 shows shoot yields of *Atriplex cuneata* grown in soil at several osmotic potentials of Na_2SO_4 and $MgSO_4$. There are no differences in shoot yields of *A. cuneata* in the no-salt control, the -5 atm treatments of Na_2SO_4 and $MgSO_4$, or the -10 atm treatments of Na_2SO_4 and $MgSO_4$. However, there was a significant difference between the -20 atm $MgSO_4$ and the -20 atm Na_2SO_4 treatments; $MgSO_4$ reduced shoot yield whereas Na_2SO_4 did not. Shoot yield of the -20 atm Na_2SO_4 + $MgSO_4$ (-10 atm Na_2SO_4 + -10 atm $MgSO_4$) treatment was the same as the -20 atm $MgSO_4$ treatment. The shoot yield of the -30 atm Na_2SO_4 treatment was as great as the -20 atm $MgSO_4$ shoot yield. Shoot growth in the -30 atm $MgSO_4$ treatment was only about half that of the control.

The data indicate that *Atriplex cuneata* and perhaps other species are more tolerant to Na_2SO_4 than $MgSO_4$, and a half mixture of Na_2SO_4 plus $MgSO_4$ is as toxic as $MgSO_4$ alone. Processed oil shale samples vary in their ratios of Na_2SO_4 to $MgSO_4$. It is concluded from the above data that *Atriplex cuneata* and probably other salt tolerant species will perform less well as the proportion and total content of $MgSO_4$ in the processed oil shale increases.

Table 8. Shoot yields of *Atriplex cuneata* grown at various osmotic concentrations of Na_2SO_4 and $MgSO_4$.

Osmotic Potential	Shoot Yield (Dry Weight in Grams) Na_2SO_4	$MgSO_4$	Na_2SO_4 + $MgSO_4$
0 atm	3.7530a	3.7530a	3.7530a
-5 atm	3.7191a	3.5664a	-
-10 atm	3.9597a	3.8764a	-
-20 atm	3.8424a	2.8834b	2.9609b
-30 atm	2.9172b	1.9923c	-

means followed by the same letter are not significant at the .05 level using Duncan's multiple range test.

C. Greenhouse Performance of Selected Shrubs in Gallon Pots Filled with Paraho Processed Shale.

The success of growing shrubs either as bare-root stock or as container-grown stock in gallon pots of processed shale varies with species and with type of planting stock. Bare-root stock had an average survival of 40 percent while container stock showed 64 percent success and that planted as container-grown stock in regular soil produced 76 percent live plants (Table 9).

Plant survival from those plants receiving added fertilizer at the rate of 100 lbs. N and 100 lbs. P_2O_5 per acre were not as high as those not receiving fertilizer. The bare-root stock without fertilization had an average 57 percent survival while that receiving fertilizer had 24 percent. The container-grown plants in spent shale without fertilization showed 71 percent survival and those with fertilization only 57 percent.

Table 9. Survival and growth of shrubs transplanted in [illegible] gallon pots of paraho processed shale. Averages of 3 replications.

		Survival		Average Height of Live Plants		
Species	Treatment[1]	June 30 1976	Dec 3 1976	Dec. 10 1976	June 30 1976	Dec. 3 1976
		%	%	cm	cm	cm
Cuneate saltbush	A	100	100	2.8	9.0	9.5
	B	100	33	1.8	21.0	22.0
	C	100	100	3.3	6.8	9.3
	D	100	33	2.8	15.0	17.0
	E	100	100	-	12.5	12.5
Mat saltbush	A	100	100	4.5	6.5	6.5
	B	100	67	5.0	8.0	13.5
	C	100	100	3.3	5.3	6.5
	D	100	33	2.7	7.0	7.0
	E	100	100	2.8	6.0	6.0
Greasewood	A	100	33	22.3	12.5	24.0
	B	100	33	17.7	21.3	22.0
	C	100	33	19.0	23.2	21.0
	D	100	100	19.0	24.3	29.0
	E	100	100	25.5	30.3	33.6
Big sagebrush	A	0	0	4.8	-	-
	B	0	0	6.0	-	-
	C	33	0	3.8	4.5	-
	D	33	0	3.2	4.5	-
	E	100	100	4.5	6.3	8.6
Shadscale saltbush	A	100	100	4.7	5.5	6.0
	B	0	0	5.8	-	-
	C	100	100	3.3	7.0	7.0
	D	100	100	5.0	17.3	17.3
	E	100	100	5.3	15.5	15.5
Fourwing saltbush	A	67	67	3.8	7.0	11.5
	B	33	33	4.2	5.0	18.0
	C	67	67	1.7	20.7	25.0
	D	67	67	2.2	36.3	53.5
	E	33	33	1.5	53.0	53.0
Siberian salt tree	A	33	0	7.5	6.0	-
	B	0	0	8.0	-	-
	C	100	100	6.8	7.5	12.0
	D	100	67	6.3	6.8	8.5
	E	0	0	4.5	-	-

---

[1] Treatments — Transplanted into shale Dec. 10-30, 1975

A. Bare root plant in spent shale

B. Bare root plant in spent shale plus fertility added at rate of 100 N per acre and 100 P_2O_5 per acre

C. Container grown plant in spent shale

D. Container grown plant in spent shale plus fertility same as Treatment B

E. Container grown plant in regular soil

The reason for this is not known. Vegetative growth was just the reverse as it was definitely influenced by the added fertility. Bare-root stock without fertilization (all of treatment A) had an average vegetative growth increase of 3.9 cm (December 1976 plant height minus December 1975 height) for one year's growth compared to 11.7 cm during the same period fo those receiving added fertilization (all of treatment B). Container-grown stock not receiving fertility produced new vegetative growth of 7.4 cm (all of treatment C) while those receiving the added fertility put on 15.7 cm of new growth (all of treatment D). Container-grown plants grown in regular soil grew 12.6 cm for the year.

A few other shrubs and two grasses were planted as container-grown stock into half gallon pots of processed shale in December, 1975. The survival and gorwth of these plants are given in Table 10. The two best shrubs were seepweed and *Kochia prostrata*. Greene's rabbitbrush did well where it received the added fertilization. Inland saltgrass survived better than western wheatgrass.

Table 10. Survival and growth of several container grown shrubs and 2 grasses transplanted into half gallon pots of paraho processed shale. Average of 3 replications from 2 fertility levels.

		Survival		Average Growth of Live Plants	
Species	Treatments*	June 30 1976	Dec. 3 1976	June 30 1976	Dec. 3 1976
		%	%	cm.	cm.
Tamarisk	A	0	0	–	–
	B	0	0	–	–
Snakeweed	A	0	0	–	–
	B	0	0	–	–
Greenes rabbitbrush	A	0	0	–	–
	B	67	67	11	25
Black sagebrush	A	33	33	3	4
	B	0	0	–	–
Seepweed	A	67	67	22	25
	B	100	100	13	19
Eriogonum (narrow leaf)	A	0	0	–	–
	B	0	0	–	–
Eriogonum (broad leaf)	A	0	0	–	–
	B	33	33	7.5	1
Kochia prostrata	A	33	33	11	20
	B	67	67	10	27
Western wheatgrass	A	33	33	Not determined	
	B	33	0	Not determined	
Inland saltgrass	A	67	67	Not determined	
	B	67	67	Not determined	

Treatments:

A. Control

B. Fertility added at rate of 100 lbs. N per acre and 100 lbs. P_2O_5 per acre.

Transplanted as container grown stock into half gallon pots containing processed shale in December, 1975.

VII. GERMINATION AND ESTABLISHMENT OF CHEATGRASS AND RUSSIAN THISTLE ON PARAHO PROCESSED SHALE.

Weather and the modifying influence of transplanted shrubs may gradually change the physical and chemical characteristics of processed shale deposits as part of the initial stages of soil succession. In the absence of rehabilitation plantings or in addition to such plantings, plant succession will probably involve the invasion of aggressive annual plants having a wide range of environmental tolerances. On Utah oil shale tracts U-a and U-b, *Bromus tectorum* (cheatgrass) and *Salsola kali* (Russian thistle) are present in great numbers, have high seed production and are presumably well-disseminated. These species could be pioneering annuals since they are known to be pioneering invaders with a wide ecological amplitude and their invasion onto the present site attests to their aggressiveness.

Cheatgrass grows mostly in the 6-22 inch precipitation zone. It often germinates in the fall and survives the winter under the snow, entering a rapid growth phase when spring moisture and temperature permit. The optimum temperature for germination increases until the seeds are 7 weeks old. At seven weeks the optimum temperature for germination is 15-20 C and one-year-old seeds have an optimum temperature of 20 C. Germination is much better in the dark than in light, but planting depths should not exceed 4 cm. Harris (1967) found that cheatgrass germinated equally well at 0, -6.2 and -11.4 atm of osmotic pressure and Rickard, et al. (1973) found that cheatgrass can establish itself in the high sodium soil under greasewood.

The rooting habit of cheatgrass is important to the methods used in this study. Hulbert's (1955) review states that cheatgrass is generally assumed to be a shallow-rooted species but he found evidence in the literature that cheatgrass roots may penetrate more than a foot. His own studies showed that the roots penetrate behond a food before spring growth begins. By June 10, when the plants were mature, the roots were found at a depth greater than three feet although much of the root biomass was in the first foot of soil. He also found that nitrate fertilizer increased root biomass as well as water use by cheatgrass.

Finally, seed production is an important factor in sustaining the invasion of a plant species. Cheatgrass produces large quantities of seed in unfavorable conditions where plants attain a height of only 4-5 cm.

Russian thistle is a drought tolerant, aggressive, introduced weed occurring throughout the western United States. It is a late spring, summer or fall annual and thrives on disturbed soils (Wallace et al. 1968). Russian thistle is one of the first invaders in *Artemisia*-dominated vegetation (Young and Evans 1972). It is a successful colonizer because it can produce from 100,000 to 200,000 seeds per plant (Robbins et al. 1952) depositing the seeds as the dead plant "tumbles" across the landscape.

Russian thistle seeds must be covered for optimum germination. Warm temperatures and a moderate moisture supply are necessary for germination (Wallace et al. 1968). They found that seeds germinated satisfactorily at 17 C and 9.1 percent soil moisture. Seeds could emerge from depths as great as 7.5 cm but not from 13 cm. Russian thistle germination is not severly limited by low osmotic potentials. Germination was 60 percent at -15 atm osmotic pressure and near 90 percent at -6 atm of stress (Young and Evans 1972). Russian thistle seeds germinate in minutes when conditions are proper. The seeds contain fully differentiated seedlings coiled in a helix (Wallace et al. 1968).

Finally, part of the success of Russian thistle in the arid west can be attributed to its water use efficiency. In a greenhouse study, Dwyer and Wolde-Yohannis (1972) found that a field capacity Russian thistle used 222 grams of water to produce one gram of shoot, while only 76 grams of water were used to produce one gram of total dry matter at 0.1 atm available water. Russian thistle apparently increases in transpiration efficiency at low soil moisture (Wallace 1970).

Knowing the salinity and pH tolerances and the minimum fertility requirements of cheatgrass and Russian thistle would be useful in predicting the circumstances favorable for invasion of these pioneer species under the transplanted shrubs and the bare interspaces, the main objective of this study was to determine the germination, establishment and survival tolerances of cheatgrass and Russian thistle on processed shale of various salinities and pH's.

A second objective was to compile pertinent data about the physical and chemical properties of the Paraho process shale. Some analyses of pH, salinity and nutrients have been conducted, but a full compliment of data such as anions, cations, macro-elements, micro-elements and partical size distribution are needed to fully appreciate the properties of Paraho processed shale as a plant growth medium.

Another objective was to determine the germination, establishment and survival characteristics of cheatgrass and Russian thistle on soil layers of various depths over processed shale and mixed with processed shale. Covering processed shale with soil is a potential alternative to planting directly on processed shale.

A. Methods

To achieve the objectives listed, chemical and physical data were determined by the Soil, Plant and Water Analysis Laboratory at Utah State University. To test criteria for successful invasion on the different shale and/or soil substrates, germination and establishment of cheatgrass and Russian thistle were assessed in greenhouse studies and field test plots. The field test plots will be evaluated for several years and are not presented in this report.

To determine whether leaching processed shale would improve the germination and establishment of cheatgrass and Rbssian thistle, these species were planted in leached processed shale. Increasing amounts of water passing through a column of shale will decrease salinity. Using knowledge of the amount of water required to decrease the electrical conductivity of the saturation extract, treatments 1-3 were conducted (Table 11).

To determine if adjusting pH to between eight and nine would improve germination and establishment and to examine the interaction of acid treatment with leaching, treatments 4-6 were studied. The pH of eight and nine was chosen because the test species, cheatgrass and Russian thistle are often found on soils in this pH range. Ten percent sulfuric acid was used to adjust pH.

To test the hypothesis that there is a minimum level of N and P_2O_5 required by cheatgrass and Russian thistle for establishment, processed shale was fertilized with various levels of ammonium nitrate and treble super phosphate. Leached and unleached shale were fertilized in treatment 7-24 to determine any interaction between fertility and salinity.

Table 11. List of treatments used to study germination and establishment of cheatgrass and Russian thistle on Paraho processed oil shale.

Treatment No.	Description
1	Unleached shale (EC 14 mmhos/cm)*
2	Leached chale (EC 11 mmhos/cm)*
3	Leached shale (EC 10.5 mmhos/cm)*
4	Unleached shale adjusted to pH 8 with H_2SO_4*
5	Leached shale adjusted to pH 8 with H_2SO_4*
6	Unleached shale adjusted to pH 8 followed by leaching*
7	Unleached shale 0 lbs. N/A, 0 lbs. P_2O_5/A
8	25 " 0 "
9	50 " 0 "
10	0 " 50 "
11	25 " 50 "
12	50 " 50 "
13	0 " 100 "
14	25 " 100 "
15	50 " 100 "
16	Leached shale 0 " 0 "
17	25 " 0 "
18	50 " 0 "
19	0 " 50 "
20	25 " 50 "
21	50 " 50 "
22	0 " 100 "
23	25 " 100 "
24	50 " 100 "
25	2" soil/4" shale*
26	6" soil/6" shale*
27	1:3 mix soil and shale*
28	1:1 mix soil and shale*
29	Southern Canyon soil*

*70 lbs N/A, 200 lbs P_2O_5/A

One alternative to planting directly in processed shale deposits is to cover the shale deposits with a layer of soil. Russian thistle and cheatgrass species were planted in 2-inch and 6-inch layers of soil over processed shale. The soil was collected from Southam Canyon, the proposed site of processed shale deposits, on lease tract Ua.

Soil mixing was also used to ameliorate the harsh characteristics of processed shale. To test whether cheatgrass and Russian thistle germination can be improved by mixing soil and shale, these species were planted in two difference mixtures and soil alone.

All of the greenhouse treatments were conducted concurrently, one species at a time, so that all treatments on a single species could be compared and control treatments did not have to be repeated. Two hundred seeds were planted in gallon cans containing the soil or shale. a 6-inch extention was placed on top of the cans used in the 6 inches of soil over 6 inches of shale treatment.

The different greenhouse treatments were irrigated by adding enough water to bring the top 3 inches to field capacity. Anytime this 3-inch portion reached one-third field capacity by weight it was irrigated again to field capacity. The seeding trials that did not involve fertilization as a study treatment were fertilized at the rate of 70 lbs. N/A and 200 lbs P_2O_5/A as described by Berg (1973). Greenhouses for studies during the fall, winter and spring of 1975-1976 were located in Arroyo Grande, California. Planting rates were 200 seeds per pot with four replications per treatment.

The following attributes were measured or observed as the experiments progressed to plant reproduction or plant death:

a. periodic height measurements
b. biomass of roots and shoots at end of study
c. conductivity and pH at beginning and end of study
d. root growth habits (especially growth at the soil-shale interface)
e. timing of life cycle events such as emergence, first leaf stage, and flowering
f. deviations from control show as growth habits or color.

This study provided information about the adjustment of Paraho processed shale which must occur to meet the tolerance range of cheatgrass and Russian thistle. Knowledge of the degree of salinity and pH adjustment needed to accommodate these species coupled with knowledge of the rate of adjustment would make it possible to predict the initiation of invasion of these two species. The rate of salinity and pH alteration must be determined in a long term field leaching study subsequent to this study.

B. Results

1. Salinity and pH. Conductivity of the shale decreased in the bottom 2.5 cm and increased in the top 2.5 cm during the treatments of cheatgrass and Russian thistle (Tables 12 and 13). Increased surface salinity was not as great in the Russian thistle treatments as in the cheatgrass treatments. This may have been the result of uncontrolled irrigation by rain when the greenhouse was damaged. Excessive irrigation may have flooded the pots, removing salts. Even with reduced salts the trend in salt movement was the same in cheatgrass and Russian thistle treatments.

In soil over shale (treatments 25 and 26) the soil conductivity increased, with the bottom of the soil layer increasing more than the top. Conductivity did not change when plants were grown on soil (treatment 29) as a control. Salinity was highest in shale treated [illegible].

Table 12 Electrical conductivity and pH of processed oil shale and desert soil before and after 29 treatments on cheatgrass.

	Conductivity ($mmhos/cm^2$)			pH		
	Before	After		Before	After	
Treatment Number	------	Top	Bottom	------	Top	Bottom
1	13.9	30.2	12.1	8.7	8.7	8.6
2	11.0	24.8	11.9	8.8	8.7	8.6
3	10.5	25.9	9.1	8.7	8.6	8.5
4	23.2	46.3	13.0	8.5	8.5	8.6
5	21.5	65.2	10.2	8.4	8.5	8.4
6	20.0	41.6	14.9	8.6	8.7	8.6
7	13.9	27.8	12.5	8.7	8.7	8.7
8	13.9	34.2	10.6	8.7	8.7	8.6
9	13.9	24.2	11.7	8.7	8.6	8.6
10	13.9	37.0	8.1	8.7	8.7	8.6
11	13.9	41.0	11.3	8.7	8.8	8.7
12	13.9	37.6	9.1	8.7	8.8	8.8
13	13.9	49.2	8.4	8.7	8.8	8.7
14	13.9	41.6	11.3	8.7	8.8	8.6
15	13.9	39.8	10.4	8.7	8.8	8.6
16	10.5	29.8	9.0	8.8	8.7	8.6
17	10.5	32.3	8.4	8.8	8.7	8.7
18	10.5	31.9	8.7	8.8	8.7	8.6
19	10.5	32.7	8.2	8.8	8.7	8.7
20	10.5	30.6	8.3	8.8	8.8	8.7
21	10.5	29.6	7.1	8.8	8.8	8.6
22	10.5	42.8	7.5	8.8	8.7	8.6
23	10.5	30.4	9.9	8.8	8.7	8.6
24	10.5	35.3	8.4	8.8	8.7	8.6
25 (shale)	13.9	12.4	7.0	8.7	8.6	8.5
(soil)	0.7	5.4	-	8.5	8.7	-
26 (shale)	13.9	9.3	10.2	8.7	8.6	8.5
(soil)	0.7	3.9	7.5	8.5	8.5	8.5
27	8.5	14.6	8.0	8.7	8.6	8.5
28	5.5	9.5	7.2	8.7	8.5	8.5
29	0.7	0.7	0.7	8.5	8.5	8.5

Table 13. Electrical conductivity and pH of processed oil shale and desert soil before and after 29 treatments on russian thistle.

	Conductivity (mmhos/cm^2)			pH		
	Before	After		Before	After	
Treatment Number	------	Top	Bottom	------	Top	Bottom
1	13.9	10.1	5.9		8.5	8.5
2	12.5	18.4	7.4		8.4	8.5
3	12.0	19.8	8.4		8.5	8.3
4	21.3	15.3	8.3		8.3	8.3
5	18.2	17.1	7.6		8.5	8.5
6	11.0	17.4	7.3		8.6	8.5
7	13.9	13.3	6.8		8.3	8.3
8	13.9	14.6	8.9		8.5	8.5
9	13.9	15.7	7.1		8.5	8.4
10	13.9	24.4	9.1		8.5	8.5
11	13.9	20.0	8.0		8.4	8.5
12	13.9	27.6	8.0		8.5	8.3
13	13.9	27.7	7.2		8.3	8.4
14	13.9	19.9	8.5		8.3	8.3
15	13.9	19.3	7.9		8.5	8.5
16	12.0	10.0	7.1		8.4	8.5
17	12.0	18.4	8.7		8.4	8.4
18	12.0	15.3	8.5		8.4	8.3
19	12.0	11.0	5.1		8.5	8.4
20	12.0	15.5	7.9		8.5	8.4
21	12.0	12.7	8.4		8.6	8.5
22	12.0	20.6	8.8		8.4	8.5
23	12.0	10.6	6.4		8.6	8.4
24	12.0	9.7	7.5		8.5	8.3
25 (shale)	13.9	19.1	5.6	8.6	8.5	8.3
(soil)	0.7	4.8	---	8.4	8.4	8.4
26 (shale)	13.9	17.4	5.6	8.6	8.5	8.5
(soil)	0.7	2.9	7.0	8.4	8.4	8.3
27	8.5	13.5	9.7	8.4	8.3	8.3
28	5.5	10.1	7.5	8.5	8.4	8.4
29	0.7	0.7	0.7	8.3	8.4	8.3

The shale tended to decrease in pH only slightly during the treatments remaining in the rage of 8.3 - 8.8.

2. Seedling Emergence. Emergence of cheatgrass and Russian thistle was quicker in treatments 25, 26 and 29 where soil alone or soil over shale was used as the plant growth medium (Tables 14 and 15). Emergence tended to be faster in leached shale than in unleached shale. Cheatgrass emergence was very poor or failed completely on shale treated with sulfuric acid. Russian thistle seedlings were able to germinate and emerge on shale treated with sulfuric acid.

3. Height. a. Cheatgrass. The height results presented are based on the first ten weeks. After 24 weeks, height did not change significantly from height at ten weeks except where the inflorescence emerged. During the first three weeks height increase of the seedlings was rapid on all treatments (Table 16); but most did not increase in height after the third or fourth week. The exceptions to this trend were plants on those treatments which showed the greatest increase in height in the first ten weeks.

Plants grown on soil alone or soil over shale increased in height through the tenth week. Plants on soil-shale mixtures also increased in height to the tenth week but at a slower rate.

At the end of the tenth week there were significant differences in the height among plants on many of the treatments (Figure 4) and a few of these differences are noteworthy. Plants on treatments 24, 25 and 29 (Table 11) produced significantly greater heights than other treatments. Mixing soil and shale in a 1:1 ratio was also quite successful

Table 14. Mean emergence (%) for cheatgrass planted in 29 treatments of oil shale or soil on October 26, 1975.

	Date (1975)				
Treatment Number	O/31	N/2	N/5	N/8	N/15
1	0	5	22	33	36 de[1]
2	0	14	35	46	50 cd
3	0	8	26	37	44 d
4	0	0	0	0	0 f
5	0	0	0	0	0 f
6	0	0	0	2	2 f
7	0	2	11	19	25 e
8	0	7	22	34	37 d
9	0	3	12	21	24 e
10	0	18	37	44	46 cd
11	0	4	19	29	34 de
12	0	4	27	39	43 de
13	0	9	25	42	42 de
14	0	4	21	32	35 de
15	0	6	21	29	32 de
16	0	20	39	49	51 cd
17	0	7	25	34	35 de
18	0	5	27	37	38 de
19	0	15	36	44	46 cd
20	0	8	35	44	46 cd
21	0	12	25	34	36 de
22	0	10	35	48	48 cd
23	0	13	29	40	41 de
24	0	16	26	35	37 de
25	0	56	82	86	86 a
26	4	42	63	77	77 a
27	0	12	24	34	41 de
28	0	25	50	61	62 bc
29	7	44	62	75	75 ab

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[1] Means followed by the same letter are not significantly different at the .05 level.

Table 15. Mean emergence (%) for russian thistle planted in 29 treatments of oil shale or soil on February 6, 1976.

	Date (1976)						
Treatment Number	F/13	F/16	F/21	F/28	M/6	M/27	A/5
1	26	30	37	39	39	39	39
2	25	28	33	41	42	42	42
3	24	27	33	41	42	44	44
4	25	26	37	41	45	46	46
5	25	25	34	41	42	43	44
6	25	25	37	41	41	45	45
7	24	30	37	40	41	41	41
8	24	30	37	40	41	41	41
9	23	30	36	39	40	41	41
10	25	30	35	39	41	41	41
11	26	30	38	40	41	41	41
12	24	30	38	40	43	43	43
13	25	30	39	41	41	41	41
14	25	30	37	40	41	41	41
15	26	30	39	40	41	41	41
16	25	30	41	46	46	46	46
17	24	30	41	46	48	48	48
18	25	30	41	45	47	47	47
19	25	30	41	47	48	48	48
20	24	30	39	43	49	49	49
21	25	30	40	44	46	46	46
22	25	30	41	45	48	48	48
23	24	30	40	47	50	50	50
24	26	30	41	46	47	47	47
25	27	30	44	45	49	51	51
26	25	28	39	48	51	58	58
27	25	25	32	37	37	37	37
28	25	28	36	41	41	41	41
29	25	30	40	45	51	54	54

Table 16. Mean heights (mm) of cheatgrass seedlings on 29 processed oil shale treatments for 10 weeks following planting on October 27, 1975.

Treatment Number	N2	N5	N8	N15	N22	N29	D6	D14	J4
1	3	10	22	28	30	31	31	34	36fghi[1]
2	4	12	25	36	38	41	41	43	51d
3	4	12	23	38	41	43	44	46	51d
4	0	0	0	0	0	0	0	0	0o
5	0	0	0	0	0	0	0	0	0o
6	0	0	9	16	17	20	15	15	15n
7	3	9	12	21	21	21	23	24	25m
8	3	12	21	28	29	29	29	29	31ijklm
9	4	10	19	27	27	27	28	29	29lm
10	4	11	20	28	28	28	29	29	30jklm
11	4	10	23	28	29	29	29	29	29lm
12	5	12	23	35	36	37	38	38	38efgh
13	4	9	19	25	28	28	28	29	29klm
14	3	10	21	30	33	34	34	34	34ghijkl
15	3	11	22	32	34	35	36	36	36fghi
16	5	12	21	29	30	31	32	33	33hijkl
17	3	12	24	33	35	35	35	35	35jghijk
18	2	12	21	28	31	32	33	34	34ghijkl
19	4	11	20	30	30	30	31	33	33hijkl
20	4	14	24	36	38	40	40	40	40ef
21	5	14	24	31	33	33	34	35	36fghij
22	4	11	21	28	30	30	31	31	35fghijk
23	5	12	24	34	34	35	35	38	38efgh
24	5	12	23	32	34	35	36	37	39efg
25	10	22	33	43	45	50	53	58	66b
26	8	20	33	46	49	55	68	76	95a
27	5	13	22	30	31	31	35	36	43e
28	7	15	25	33	33	35	40	50	70c
29	11	21	33	39	44	49	55	64	84b

[1] Means followed by the same letter are not significantly different at the .05 level.

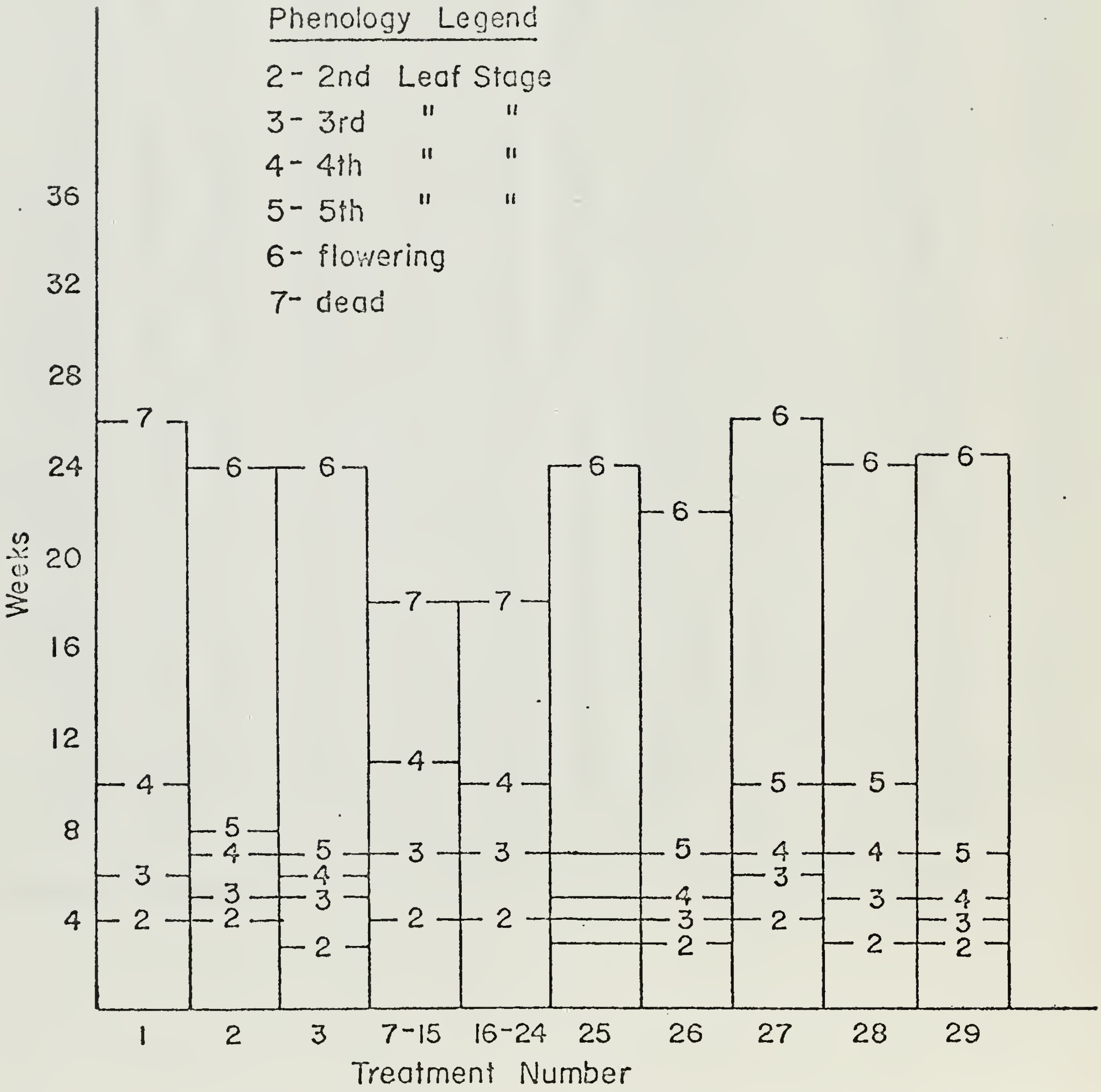

FIGURE 4. Phenology of cheatgrass grown on processed oil shale and soil.

in increasing plant growth when compared with shale alone or soil and shale mixed in a 1:3 ratio. In treatments 2 and 3, where the processed shale was leached and fertilized at the rate of 70 lbs N/A and 200 lbs P_2O_5/A, seedling heights were significantly higher than those seedlings which were fertilized at lower rates. Finally, it is noteworthy that the three treatments using H_2SO_4 as an ammendment for reducing high pH were unsuccessful. Plants on two of the treatments failed to emerge and the third treatment produced seedlings but they were dead by the tenth week.

b. *Russian thistle*. Soil alone or soil over shale treatments produced seedlings with significantly greater heights on April 5 than the other treatments (Table 17). The mixture of soil and shale in a 1:1 ratio and 1:3 ratio produced some of the smallest height increases of all the Russian thistle treatments. These treatments were among the most successful for cheatgrass.

Where seedlings were grown on processed shale, the leached treatments fertilized with 25 lbs N/A and 100 lbs P_2O_5/A produced greater heights in two months than all other treatments using shale alone. Generally, leaching produced greater seedling heights than no leaching. The treatments using sulfuric acid as a pH amendment were successful in producing Russian thistle seedlings in contrast to the general failure of cheatgrass to establish on these treatments.

C. Biomass

Cheatgrass on treatments 26 and 29 produced the most biomass followed by those on treatments 25 and 28 (Table 18). Cheatgrass on treatments 2, 25, 26, 27, 28 and 29 produced more than one gram of biomass. Russian

Table 17. Mean heights (mm) of russian thistle seedlings on 29 oil shale treatments (Table 1) over a 2 month period. Seeds were planted on February 6.

Treatment Number	F13	F16	F21	F28	M6	M27	A5	
1	26	30	37	39	39	39	39[1]	kl
2	25	28	33	41	42	42	42	hi
3	24	27	38	41	42	44	44	n
4	25	25	37	41	41	45	45	i
5	25	25	34	41	42	44	44	j
6	25	26	37	41	45	46	46	kl
7	24	30	37	40	41	41	41	lm
8	24	30	37	40	41	41	41	lm
9	23	30	36	39	40	41	41	m
10	25	30	35	39	41	41	41	lm
11	26	30	38	40	41	41	41	lm
12	24	30	38	40	41	43	43	kl
13	25	31	39	41	41	41	41	lm
14	25	30	37	40	41	41	41	m
15	26	30	39	40	40	41	41	lm
16	25	30	41	46	46	46	46	hi
17	24	30	41	46	48	48	48	e
18	25	30	41	45	47	47	47	gh
19	25	30	41	47	48	48	48	ef
20	24	30	39	43	49	49	49	de
21	25	30	40	44	46	46	46	i
22	25	30	41	45	48	48	48	ef
23	24	30	40	47	50	50	50	d
24	26	30	41	46	47	47	47	fg
25	27	30	44	45	49	51	51	c
26	26	28	39	48	51	54	56	a
27	25	25	32	37	37	37	37	n
28	25	28	36	41	41	41	41	m
29	27	30	40	45	51	54	54	b

[1] Means followed by the same letter are not significantly different at the .05 level.

Table 18. Mean total biomass and root - shoot ratios for 29 treatments on cheatgrass.

Treatment Numbers	Total Biomass (g)	Root - Shoot Ratios
1	0.35 d[1]	0.45
2	2.00 c	0.25
3	0.68 d	0.24
4	0 d	0
5	0 d	0
6	0 d	0
7	0.19 d	0.9
8	0.31 d	0.55
9	0.18 d	0.87
10	0.26 d	0.44
11	0.23 d	0.64
12	0.10 d	0.23
13	0.18 d	0.8
14	0.31 d	0.19
15	0.21 d	0.62
16	0.41 d	0.46
17	0.4 d	0.33
18	0.43 d	0.23
19	0.31 d	0.72
20	0.60 d	0.13
21	0.70 d	1.33
22	0.43 d	0.43
23	0.66 d	0.18
24	0.73 d	0.26
25	6.55 b[2]	0.47
26	12.5 a[3]	0.51
27	2.76 c	0.3
28	7.13 b	0.4
29	13.37 a	0.35

---

[1] Means followed by the same letter are not significantly different at the .05 level.

[2] 80 percent of the roots were in the soil layer.

[3] 89 percent of the roots were in the soil layer.

thistle, on treatments 25, 26 and 29, produced the most biomass followed by those on treatments 15, 18 and 19 (Table 19). Plants on all other treatments produced less than one gram of biomass. Root-shoot ratios were not useful in showing treatment affects.

D. Phenology

The treatments that resulted in the greatest increase in plant height also caused the most rapid phenological development (Figures 4 and 5). Cheatgrass on treatments 23, 25, 26 and 28 flowered by early April, while plants on most other treatments died by the end of February without flowering. Most of these seedlings never progressed beyond the fourth leaf stage. On March 25, 1976, some treatments contained a few seedlings which were beginning to flower. By April 1, 1976, all seedlings were flowering in these treatments while many other treatments were just beginning to flower or had not flowered at all.

Observation of the cheatgrass seedlings showed that yellowing of the leaf tips was common on those plants growing on shale. Also, the first leaf dried sooner on plants grown directly on shale than on plants grown on soil. Observation of the Russian thistle seedlings have shown that the first leaf on most seedlings on shale turned yellow while this yellowing was not apparent on seedlings growing on soil or soil over shale.

Cheatgrass treatments which were not fertilized with P_2O_5/A showed a dominant anthrocyanin pigmentation which is a classic symptom of phosphorous deficiency. Plants fertilized with the highest rate of P_2O_5 showed little of this purple pigmentation.

Table 19. Mean total biomass and root - shoot ratios for 29 treatments on russian thistle.

Treatment Numbers	Total Biomass (g)	Root - Shoot Ratios
1	0.73 cd	0.81
2	0.55 d	0.69
3	0.43 d	0.55
4	0.58 cd	0.77
5	0.33 d	0.44
6	0.48 d	0.90
7	0.48 d	0.58
8	0.63 cd	0.67
9	0.53 d	0.75
10	0.73 cd	0.61
11	0.85 bcd	0.70
12	0.68 cd	1.10
13	0.88 bcd	0.67
14	0.78 bcd	1.07
15	1.10 bc	1.33
16	0.53 d	0.62
17	0.40 d	0.55
18	1.20 b	1.00
19	1.20 b	1.18
20	0.50 c	1.30
21	0.40 d	0.78
22	0.45 d	0.50
23	0.50 d	0.67
24	0.45 d	0.64
25	1.38 ab	1.20
26	1.90 a	0.74
27	0.28 d	0.83
28	0.75 cd	0.50
29	1.88 a	0.78

[1] Means followed by the same letter are not significantly different at the .05 level.

[2] 33 percent of the roots were in the soil layer.

[3] 73 percent of the roots were in the soil layer.

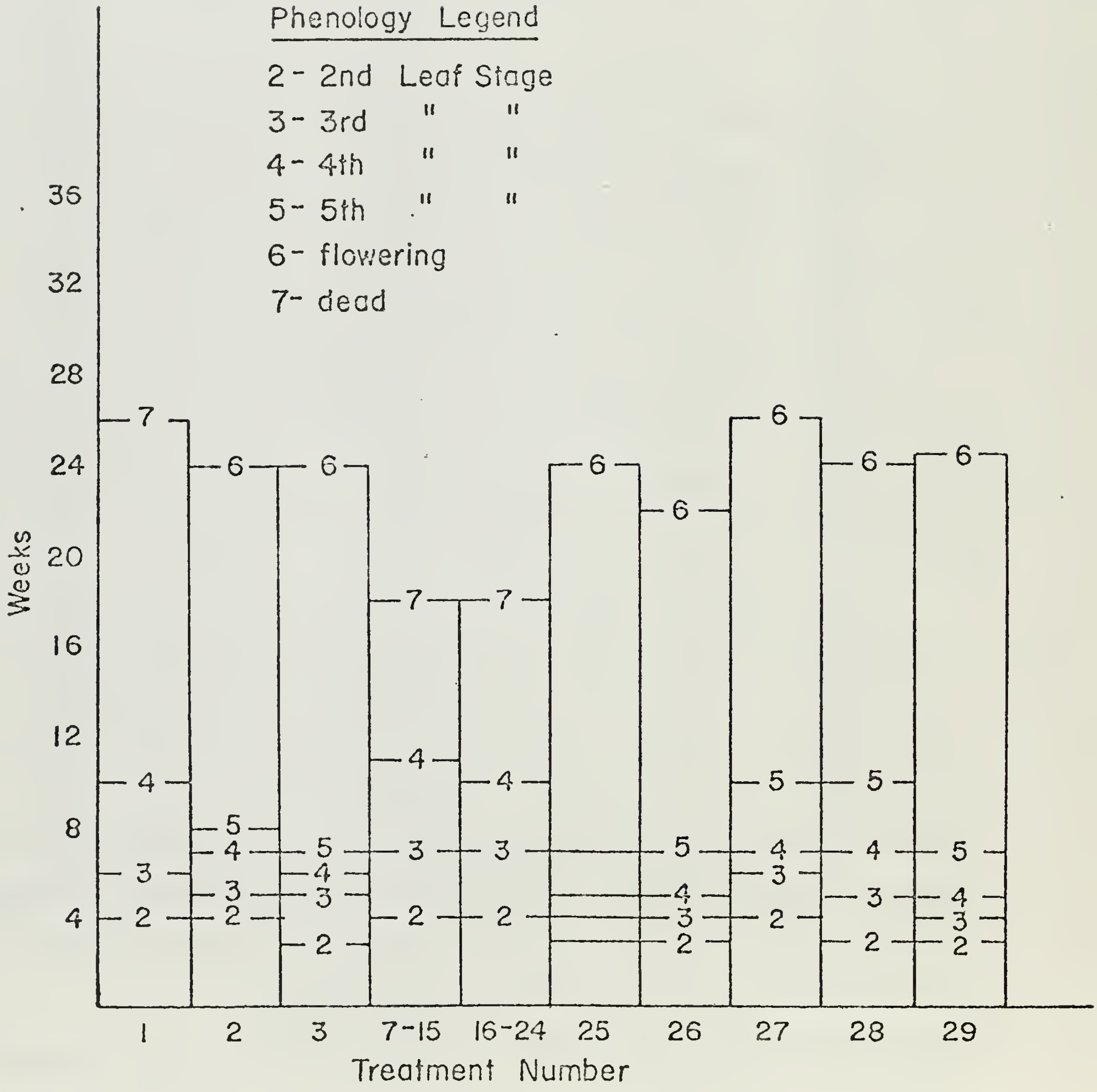

FIGURE 5. Phenology of cheatgrass grown on processed oil shale and soil.

E. Root Growth Habit

Generally roots in leached shale reached depths greater than three inches while roots in unleached shale seldom were deeper than three inches. No change in growth habit was observed where roots grew from soil into shale in treatments 25 and 26. The biomass data show that there was more root biomass in the soil treatments but that may be related to the thickness of the soil surface layer.

F. Discussion

Processed shale with a conductivity of about 14 mmhos/cm, as used in these studies, is within the salinity tolerance for germination and seedling establishment for cheatgrass. However, capillary rise during the course of the study increased the salinity in the upper layer of the pots as it decreased in the bottom of the pots. Because the cheatgrass roots were concentrated in the upper three inches of shale they were constantly subjected to higher salinity levels. Where salinity exceeded 20 mmhos/cm in the upper inch of shale at the end of the study, the cheatgrass seedlings were unproductive and generally died before producing flowers. Where soil was used to ameliorate the affects of capillary rise, conductivity was less than 20 mmhos/cm and the cheatgrass was productive and most replications survived to flower.

Russian thistle also emerged and established on processed shale with and electrical conductivity of 14 mmhos/cm. Capillary rise was apparent; however, the pots may have been flooded when rainfall damaged the greenhouse, thus reducing salinity. Because of this uncontrolled leaching it is difficult to determine whether Russian thistle can tolerate conductivities greater than 25 mmhos/cm.

Fertilizer had a slight measurable affect on the growth criteria measured in this study for either species. The negative effect of salinity probably overshadowed any positive results gained by fertilization with nitrogen and phosphorous. Had the leaching treatments in this study been more complete, the affect of fertilization might have been more pronounced.

A winter annual such as cheatgrass could successfully germinate and establish on processed shale before moisture, surface temperature, and capillary rise of salts became limiting. As capillary rise increased salinity in the root zone, cheatgrass plants might die before flowering but they still would add organic matter to the site. Addition of organic matter to the site is an important process of ecological succession because it modifies the surface temperature, decreases surface evaporation and adds nutrients, thus rendering the site more favorable for succeeding species. Cheatgrass seems to be an excellent candidate to colonize processed shale piles. Baker and Duffield (1973) found that cheatgrass was among the annual species that invaded on some test plots of TOSCO processed shale a few years after they were established.

Russian thistle is a summer annual and thus does not receive much benefit from spring snow melt. However, Russian thistle is probably better adapted to drought conditions than cheatgrass. Dwyer and Wolde-Yohannis (1972) showed that Russian thistle can increase biomass even when soil water is reduced.

SECTION VII LITERATURE CITED

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VIII. REHABILITATION PLANTINGS ON DISTURBED SITES

Data presented is a later comparison of shrub survival and growth from studies previously established. No vegetative field studies have been started since the June, 1976 report (see earlier reports for methods).

During the last of September and first of October all field plots and plantings were evaluated for survival and growth. Comparisons and results are generally shown for all dates of evaluations since the various plantings were established.

This growing season was dry with the timeliness of the few storms received not being too advantageous for plant establishment and growth.

A. Plantings Made April 25-26, 1975, of Bare-Root Seedlings on Disturbed Sites.

There continues to be a general reduction in plant survival for the nine species originally planted (Table 20). Those with a 50 percent or better survival have been fourwing saltbush, black sagebrush and big sagebrush, though this varies with site.

Losses to rodent damage have been severe, especially on drill holes G-13 and G-5. Sheep and rodent damage have both been a factor in plant survival at drill hole G-22. Adverse soil conditions at drill hole G-8 have been the major factor for poor plant survival.

The saltbushes, shadscale, fourwing and cuneate, are the species most adapted to the soil conditions at drill hole G-8.

All species planted at drill hole G-5 have survived to some extent. The sagebrushes and fourwing appearing to be the most adapted. Rodents

Table 20. Comparison of shrub species survival at four drill site locations and at four dates - Spring and Fall, 1975 and Spring and Fall, 1976 - from bare rooted plantings made in April, 1975.

Plant Species	G-5	G-22	G-8	G-13	Average
	%	%	%	%	%
A. Greasewood					
June 1975	85	93	8	70	64
Oct. 1975	63	90	0	45	49
June 1976	45	63	0	40	37
Oct. 1976	23	30	0	35	22
B. Big sagebrush					
June 1975	95	98	68	100	90
Oct. 1975	93	90	40	97	80
June 1976	70	87	15	70	60
Oct. 1976	70	55	5	70	50
C. Fourwing saltbush					
June 1975	95	100	80	90	92
Oct. 1975	88	95	65	83	83
June 1976	70	87	25	75	64
Oct. 1976	70	80	18	75	61
D. Black sagebrush					
June 1975	90	100			95
Oct. 1975	80	90			85
June 1976	70	77			73
Oct. 1976	65	48			57
E. Rubber rabbitbrush					
June 1975	87	78			83
Oct. 1975	35	67			51
June 1976	18	5			11
Oct. 1976	13	0			7
F. Winterfat					
June 1975	85	78			80
Oct. 1975	65	73			69
June 1976	50	47			49
Oct. 1976	10	13			12

Table 20 (continued)

Comparison of shrub species survival at four drill site locations and at four dates - Spring and Fall, 1975 and Spring and Fall, 1976 - from bare rooted plantings made in April, 1975.

Plant Species	G-5	G-22	G-8	G-13	Average
	%	%	%	%	%
G. Cuneate saltbush					
June 1975			80	85	83
Oct. 1975			65	63	64
June 1976			35	23	29
Oct. 1976			13	23	18
H. Shadscale					
June 1975			55	53	54
Oct. 1975			55	50	53
June 1976			40	25	33
Oct. 1976			35	23	29
I. Spreading rabbitbrush					
June 1975			90	98	94
Oct. 1975			2	85	43
June 1976			0	85	42
Oct. 1976			0	68	34
Average survival June 1976	54	61	19	53	44
Average survival Oct. 1976	42	38	12	49	32

have been especially severe on winterfat and fourwing saltbush, though the latter seems to have greater recuperative growth possibly due to its root systems. All species showed rodent damage with big sagebrush showing the least. Competition from forbs, especially russian thistle, may be having an effect on establishment, especially during drouth years.

Losses at drill site G-22 are mainly due to rodent and sheep damage and competition from other plants for moisture. The plot area had a dense cover of russian thistle, similar to drill site G-5. This appeared as a definite advantage during the moist year of 1975 as it protected, to a degree, the young plants from rodents; but they had an adverse effect during the dry growing season of 1976.

Site conditions, for the species planted, were more favorable at drill hole G-13 than at the other locations. Percent survival would have been much higher for the three saltbushes, cuneate, fourwing and shadscale, as well as greasewood, as many of these were killed by severe rodent grazing. Rabbits were especially detrimental. The other species were grazed to a less extent.

Container-grown plants of fourwing saltbush, field planted in April, 1975, show favorably in survival and growth (Table 21). Losses, from general observations, have been due mainly to sheep and rodent grazing. Even at drill site G-8 as shown in Table 22, only one container-grown fourwing saltbush has diet (this was from livestock trampling) with a 92 percent survival as compared to an 18 percent survival for bare-root stock of fourwing saltbush at the same location.

Table 21. Comparison of survival and growth of plants at four observation dates (June 12, 1975, October 21-31, 1975, June 8-10, 1976 and Oct. 1, 1976). Plants were grown in containers from cuttings and field planted in April 1975.

			Survival				Growth			
Plant Source	Sex	Number Planted	June 1975	Oct. 1975	June 1976	Oct. 1976	June 1975	Oct. 1975	June 1976	Oct. 1976
			%	%	%	%	Cm.	Cm.	Cm.	Cm.
Atca UB1	Female	16	94	94	81	75	14	37	31	28
Atca UB2	Female	14	100	100	86	79	16	32	25	27
Atca UB3	Female	14	100	100	86	86	17	41	38	39
Atca UB6	Male	10	100	100	100	100	18	39	42	49

Table 22. Survival comparison of bare root and container grown Fourwing saltbush transplants for 2 years at each of the four drill sites.

			Survival					
			Bare root			Container		
Location (Drill Site)	Original Planting Bare root	Original Planting Container	Oct. 1975	June 1976	Oct. 1976	Oct. 1975	June 1976	Oct. 1976
	No.	No.	%	%	%	%	%	%
G-5	40	12	89(5)*	70(12)	70(12)	100	92(1)*	92(1)*
G-8	40	12	65(14)	25(30)	18(33)	100	92(1)	92(1)
G-13	40	14	83(7)	75(10)	75(10)	100	86(2)	79(3)
G-22	40	16	95(2)	87(5)	80(8)	94(1)	81(3)	75(4)

*Number of plants that died shown in parenthesis.

B. A Comparison of Fall (1975) vs. Spring (1976) Direct Seeding, Planting of Bare-Root Seedlings and Plantings of Container-Grown Shrubs and Grasses

A general description of this study was included in the previous progress report (January 1, 1976-June 30, 1976).

All species from direct seeding had one or more seedlings alive either from the fall (1975) or spring (1976) plantings at the time observations were made in October, 1976 (Table 23). Some shrub species, such as greasewood, fourwing saltbush, winterfat, and spreading rabbitbrush will reproduce whether seeds are planted in the fall or spring. Others, such as the sagebrushes, will reproduce best from fall plantings. More information on seed germination and other factors are needed for establishment of other species such as shadscale and cuneate saltbushes. In general, fewer seedlings survived the summer than were observed growing in June, 1976.

A comparison of plant survival from nine shrub species from two methods of planting (bare-root and container-grown) at two seasons (Fall 1975 and Spring 1976) and applying three treatments is shown in Table 24.

In general, there was reduced plant survival from June to October. Losses were attributed to rodent damage and weed competition, especially at the Section 6 site. Ants were an additional problem. No response was observed from the added moisture and fertility treatments.

Planting bare-root stock in the spring was generally better than fall planting (fourwing saltbush, shadscale, cuneate saltbush), though with some species, survival was about equal from either time of planting (greasewood, black sagebrush, big sagebrush and spreading rabbitbrush) (Table 25). Site characteristics had some influence.

Table 23. Comparison of direct seeding nine shrub species at three locations and at 2 dates* - Fall 1975 and Spring 1976. Data shows total number of plants from 4 replications at 2 observation dates - June and October 1976.

Species	Drill Hole G-3 Fall Seeding		Drill Hole G-3 Spring Seeding		Drill Hole G-17 Fall Seeding		Drill Hole G-17 Spring Seeding		Section 6 Fall Seeding		Section 6 Spring Seeding		Total Fall Seeding		Total Spring Seeding	
	June No.	Oct No.	June No.	Oct No.	June No.	Oct No.	June No.	Oct No.	June No.	Oct No.	June No.	Oct No.	June No.	Oct No.	June No.	Oct No.
Greasewood	25	8	17	8	0	0	10	0	1	0	12	4	26	8	39	12
Fourwing saltbush	4	3	58	26	1	0	8	0	1	1	63	38	6	4	129	64
Shadscale	0	0	0	0	0	0	0	0	0	0	4	2	0	0	4	2
Cuneate saltbush	1	0	2	0	0	1	0	0	0	0	1	0	1	1	3	0
Winterfat	27	15	19	16	0	0	12	0	39	14	9	9	66	29	40	25
Greenes rabbitbrush	4	4	2	0	0	0	0	0	3	1	0	2	7	5	2	2
Black sagebrush	1	0	0	0	0	0	0	0	4	2	0	0	5	2	0	0
Big sagebrush	7	6	0	0	0	0	0	0	2	3	1	0	9	9	1	0
Spreading rabbitbrush	9	5	8	3	4	0	2	0	16	2	1	0	29	7	11	3

*Date of fall seeding - November 14, 1975
Date of spring seeding - March 23, 1976

Table 24. Comparison in transplanting at three locations, nine shrub species using two methods - bare root and container grown stock - three treatments and at two seasons - Fall 1975 and Spring 1976. Averages from 4 replications at each location. Data shows per cent survival 2 months after final planting and 5 months after final planting.

Species	Treatments*	Drill Hole G-3		Drill Hole G-17		Section 6		Average of 3 Locations	
		June %	Oct %	June %	Oct %	June %	Oct %	June %	Oct %
Greasewood	F BR A	100	100	50	50	75	75	75	75
	F BR B	100	75	25	25	25	25	50	42
	F BR C	100	100	25	25	50	25	58	50
	S BR A	25	25	100	75	75	25	67	42
	S BR B	100	75	75	75	100	25	92	58
	S BR C	100	100	75	75	100	50	92	75
	F CO A	100	100	75	75	100	75	92	83
	F CO B	100	100	100	100	100	75	100	92
	F CO C	75	100	100	100	100	100	92	100
	S CO A	100	100	50	50	100	50	83	67
	S CO B	100	100	100	100	100	75	100	92
	S CO C	100	100	100	100	100	75	100	92
Fourwing saltbush	F BR A	25	25	50	50	0	0	25	25
	F BR B	50	75	25	25	0	0	25	33
	F BR C	0	0	25	25	0	0	8	8
	S BR A	100	100	100	100	100	100	100	100
	S BR B	100	100	100	100	100	100	100	100
	S BR C	100	100	100	100	100	100	100	100
	F CO A	75	50	75	75	75	50	75	58
	F CO B	100	75	100	75	75	75	92	75
	F CO C	25	25	50	50	50	50	42	42
	S CO A	100	100	100	100	100	75	100	92
	S CO B	100	100	100	100	100	100	100	100
	S CO C	100	100	100	100	100	100	100	100

Table 24 (continued)
Comparison in transplanting at three locations, nine shrub species using two methods - bare root and container grown stock - three treatments and at two seasons - Fall 1975 and Spring 1976. Averages from 4 replications at each location. Data shows per cent survival 2 months after final planting and 5 months after final planting.

Species	Treatments*	Drill Hole G-3		Drill Hole G-17		Section 6		Average of 3 Locations	
		June %	Oct %	June %	Oct %	June %	Oct %	June %	Oct %
Cuneate saltbush	F BR A	100	75	50	50	75	50	75	58
	F BR B	75	50	100	50	50	50	75	50
	F BR C	50	25	100	100	100	75	83	67
	S BR A	100	25	100	100	100	100	100	75
	S BR B	100	50	100	100	100	100	100	83
	S BR C	75	50	100	100	75	75	83	75
	F CO A	100	75	75	50	100	75	92	67
	F CO B	75	50	100	100	75	25	83	58
	F CO C	50	25	50	50	75	75	58	50
	S CO A	75	50	100	100	100	75	92	75
	S CO B	100	25	100	100	100	100	100	75
	S CO C	100	75	100	75	100	100	100	83
Winterfat	F BR A	50	50	75	75	100	100	75	75
	F BR B	50	50	50	50	50	50	50	50
	F BR C	75	50	25	25	75	75	58	50
	S BR A	75	75	100	100	75	75	83	83
	S BR B	75	75	100	100	75	50	83	75
	S BR C	100	75	100	100	100	100	100	92
	F CO A	100	50	75	75	75	75	83	67
	F CO B	100	100	75	75	100	75	92	83
	F CO C	100	100	75	75	75	50	83	75
	S CO A	100	100	75	75	100	100	92	92
	S CO B	100	100	100	100	100	100	100	100
	S CO C	100	100	75	75	100	100	92	92

Table 24 (continued)

Comparison in transplanting at three locations, nine shrub species using two methods - bare root and container grown stock - three treatments and at two seasons - Fall 1975 and Spring 1976. Averages from 4 replications at each location. Data shows per cent survival 2 months after final planting and 5 months after final planting.

Species	Treatments*	Drill Hole G-3		Drill Hole G-17		Section 6		Average of 3 Locations	
		June %	Oct %	June %	Oct %	June %	Oct %	June %	Oct %
Greenes rabbitbrush	F BR A	75	100	50	50	75	50	67	67
	F BR B	100	100	75	75	75	50	83	75
	F BR C	75	75	100	75	75	50	83	67
	S BR A	75	100	100	100	50	25	75	75
	S BR B	100	100	100	75	100	50	100	75
	S BR C	100	100	100	75	100	50	100	75
	F CO A	75	75	100	75	75	50	83	67
	F CO B	50	50	100	100	75	25	75	58
	F CO C	100	100	100	100	50	0	83	67
	S CO A	100	100	100	100	100	0	100	67
	S CO B	100	100	100	100	100	25	100	75
	S CO C	100	100	100	100	100	0	100	67
Black sagebrush	F BR A	100	100	100	75	100	50	100	75
	F BR B	100	100	100	100	100	50	100	83
	F BR C	75	75	100	100	100	50	92	75
	S BR A	100	100	100	100	100	50	100	83
	S BR B	100	100	100	100	100	75	100	92
	S BR C	75	75	75	75	100	50	83	67
	F CO A	75	75	100	100	100	50	92	75
	F CO B	100	100	100	100	100	50	100	83
	F CO C	75	75	100	100	100	100	92	92
	S CO A	100	100	100	100	100	25	100	75
	S CO B	100	100	100	100	100	50	100	83
	S CO C	100	75	100	100	100	0	100	58

Table 24 (continued)

Comparison in transplanting at three locations, nine shrub species using two methods - bare root and container grown stock - three treatments and at two seasons - Fall 1975 and Spring 1976. Averages from 4 replications at each location. Data shows per cent survival 2 months after final planting and 5 months after final planting.

Species	Treatments*	Drill Hole G-3		Drill Hole G-17		Section 6		Average of 3 Locations	
		June %	Oct %	June %	Oct %	June %	Oct %	June %	Oct %
Big sagebrush	F BR A	25	25	100	50	50	25	58	33
	F BR B	100	100	100	100	100	100	100	100
	F BR C	75	75	100	100	100	100	92	92
	S BR A	100	100	100	100	25	0	75	67
	S BR B	100	100	100	100	75	25	92	75
	S BR C	100	100	100	100	50	25	83	75
	F CO A	100	100	100	100	75	75	92	92
	F CO B	100	100	100	100	100	100	100	100
	F CO C	100	100	100	100	100	100	100	100
	S CO A	100	100	100	100	100	50	100	83
	S CO B	100	100	100	100	75	25	92	75
	S CO C	100	100	100	100	100	75	100	92
Spreading rabbitbrush									
	F BR A	75	75	75	75	100	75	83	75
	F BR B	100	75	100	75	75	75	92	75
	F BR C	100	100	75	25	75	75	83	67
	S BR A	100	50	100	50	100	50	100	50
	S BR B	75	75	100	100	100	100	92	92
	S BR C	100	75	100	75	100	75	100	75
	F CO A	100	100	50	50	100	100	83	83
	F CO B	100	75	25	25	100	100	75	67
	F CO C	100	100	75	75	100	100	92	92
	S CO A	100	75	100	100	100	75	100	83
	S CO B	100	100	100	100	75	50	92	83
	S CO C	100	75	100	75	100	50	100	67

Table 24 (continued)

Comparison in transplanting at three locations, nine shrub species using two methods - bare root and container grown stock - three treatments and at two seasons - Fall 1975 and Spring 1976. Averages from 4 replications at each location. Data shows per cent survival 2 months after final planting and 5 months after final planting.

Species	Treatments*	Drill Hole G-3		Drill Hole G-17		Section 6		Average of 3 Locations	
		June %	Oct %	June %	Oct %	June %	Oct %	June %	Oct %
Shadscale saltbush	F BR A	50	50	75	25	50	50	58	42
	F BR B	75	25	100	100	100	100	92	75
	F BR C	75	75	75	75	100	100	83	83
	S BR A	100	50	100	100	100	100	100	83
	S BR B	100	75	100	100	100	100	100	92
	S BR C	100	25	100	100	100	100	100	75
	F CO A	100	25	75	75	100	75	92	58
	F CO B	75	75	100	100	100	100	92	92
	F CO C	75	75	75	75	100	100	83	83
	S CO A	100	50	50	50	75	75	75	58
	S CO B	100	50	100	100	100	100	100	83
	S CO C	100	75	100	100	100	100	100	92

Treatments* and Seasons

F = Fall planting date - Oct. 17 to Oct. 30, 1975
S = Spring planting date - April 1 to April 7, 1976

BR = Bare root transplanting stock
CO = Container grown transplanting stock

A = Control
B = Water at time of planting
C = Water and fertilizer at time of planting

Table 25. Percent survival of 9 shrub species using 2 methods of planting at 2 seasons and at 3 locations. Data is the average of 3 treatments and 4 replications. Observations were made in the fall of 1976.

Species	Method and Season of Planting*	Location			
		Drill Hole G-3	Drill Hole G-17	Sec. 6	Ave.
		%	%	%	%
Greasewood	F BR	92	33	42	56
	S BR	67	75	33	58
	F CO	100	92	83	92
	S CO	100	83	67	84
Fourwing saltbush	F BR	33	33	0	22
	S BR	100	100	100	100
	F CO	50	67	58	58
	S CO	100	100	92	97
Shadscale saltbush	F BR	50	67	83	67
	S BR	50	100	100	83
	F CO	58	83	92	78
	S CO	58	83	92	78
Cuneate saltbush	F BR	50	67	58	58
	S BR	42	100	92	78
	F CO	50	67	58	58
	S CO	50	92	92	78
Winterfat	F BR	50	50	75	58
	S BR	75	100	75	83
	F CO	83	75	67	75
	S CO	100	83	100	94
Greenes rabbitbrush	F BR	92	67	50	70
	S BR	100	83	42	75
	F CO	75	92	25	64
	S CO	100	100	8	69
Black sagebrush	F BR	92	92	50	78
	S BR	92	92	58	81
	F CO	83	100	67	83
	S CO	92	100	25	72

Table 25 (continued)
Percent survival of 9 shrub species using 2 methods of planting at 2 seasons and at 3 locations. Data is the average of 3 treatments and 4 replications. Observations were made in the fall of 1976.

Species	Method and Season of Planting*	Location Drill Hole G-3	Drill Hole G-17	Sec. 6	Ave.
		%	%	%	%
Big sagebrush	F BR	67	83	75	75
	S BR	100	100	16	72
	F CO	100	100	92	97
	S CO	100	100	50	83
Spreading rabbitbrush	F BR	83	58	75	72
	S BR	75	75	75	75
	F CO	92	50	100	81
	S CO	83	92	58	78

*Season of planting:

F = Fall Planting date: October 17-30, 1975
S = Spring Planting date: April 1-7, 1976

Method of planting:

BR = bare root planting stock
CO = container grown planting stock

Approximately half the species had a higher survival rate from spring planted container-grown plants while others showed no difference. Fourwing saltbush was the only species showing a highly superior preference for spring planting, whether from container or bare-root planting. Generally, the container-planted stock had a healthier appearance than the bare-rooted plantings. Growing uniform plant material is still a problem with these native plants that needs additional study.

Survival of grass species planted as bare-root clones (divisions of a grass plant) or as container-grown stock at two seasons under three treatments and at three locations is shown in Table 26. No real difference in survival was observed from those treatments receiving water or water plus fertilizer when compared with the control. Rodent grazing and competition from weeds had a negative influence on survival at Section 6. Ant colonies within the plots were also an unfavorable factor at all three locations. Weed competition may have caused some losses at drill sites 3 and 17.

Fall planting of bare-root grass clones was only about half as successful as spring planting of bare-root clones or container planting either in the fall or spring (Table 27). There was little difference in plant survival when fall planted from containers or when spring planted either from containers or as bare-root clones.

C. Effect of Root Pruning During Nursery Propagation of Shrubs.

Pruning of roots or top growth have had no measurable effect on survival. Losses have occurred to winterfat and to the Bridger ecotype

Table 26. Comparison in transplanting at three locations, five grass species using two methods - bare root and container grown stock - three treatments and at two seasons - Fall 1975 and Spring 1976. Averages from 4 replications at each location. Data shows per cent survival 2 months after planting and 5 months after final planting.

Species	Treatments*	Drill Hole G-3		Drill Hole G-17		Section 6		Average of 3 Locations	
		June %	Oct %	June %	Oct %	June %	Oct %	June %	Oct %
Indian rice grass	F BR A	50	0	25	25	0	0	25	8
	F BR B	0	0	75	50	0	0	25	17
	F BR C	75	75	75	50	0	0	50	42
	S BR A	50	50	75	75	75	75	67	67
	S BR B	100	100	100	100	100	0	100	67
	S BR C	100	100	100	100	100	25	100	75
	F CO A	75	75	75	75	25	25	58	58
	F CO B	75	75	50	50	50	25	58	50
	F CO C	75	75	100	100	75	25	83	67
	S CO A	75	75	25	0	100	0	67	25
	S CO B	100	100	50	50	100	50	83	67
	S CO C	75	75	50	25	100	0	75	33
Needle & thread thread	F BR A	75	50	75	25	0	0	50	25
	F BR B	75	25	75	25	0	0	50	17
	F BR C	25	50	100	50	25	0	50	33
	S BR A	25	25	75	50	50	25	50	33
	S BR B	75	50	100	100	25	0	67	50
	S BR C	100	100	75	75	75	25	83	67
	F CO A	50	50	100	100	100	25	83	58
	F CO B	75	50	100	100	100	0	92	50
	F CO C	75	75	50	25	100	0	75	33
	S CO A	100	100	75	75	75	50	83	75
	S CO B	100	100	100	100	100	25	100	75
	S CO C	100	100	100	100	100	25	100	75

Table 26 (continued)
Comparison in transplanting at three locations, five grass species using two methods - bare root and container grown stock - three treatments and at two seasons - Fall 1975 and Spring 1976. Averages from 4 replications at each location. Data shows per cent survival 2 months after planting and 5 months after final planting.

Species	Treatments*	Drill Hole G-3		Drill Hole G-17		Section 6		Average of 3 Locations	
		June %	Oct %	June %	Oct %	June %	Oct %	June %	Oct %
Fairway wheatgrass	F BR A	100	100	100	75	75	25	92	67
	F BR B	75	75	75	50	50	25	67	50
	F BR C	75	50	50	0	50	25	58	25
	S BR A	100	100	100	50	100	100	100	83
	S BR B	100	100	100	75	100	100	100	92
	S BR C	100	100	100	100	100	100	100	100
	F CO A	50	50	100	100	100	100	83	83
	F CO B	75	75	100	75	100	100	92	83
	F CO C	75	75	100	75	100	75	92	75
	S CO A	50	50	100	100	100	25	83	58
	S CO B	100	100	100	75	75	50	92	75
	S CO C	100	100	75	75	75	75	83	83
Western wheat grass	F BR A	100	50	75	50	100	75	92	58
	F BR B	100	75	75	50	75	50	83	58
	F BR C	100	100	100	75	100	75	100	83
	S BR A	25	25	75	50	100	100	67	58
	S BR B	100	75	100	50	100	100	100	75
	S BR C	100	100	100	50	100	100	100	83
	F CO A	100	100	100	100	100	100	100	100
	F CO B	100	100	100	75	100	75	100	83
	F CO C	100	100	100	100	100	100	100	100
	S CO A	75	50	100	100	100	50	92	67
	S CO B	100	100	100	100	75	75	92	92
	S CO C	100	100	100	75	100	75	100	83

Table 26 (continued)

Comparison in transplanting at three locations, five grass species using two methods - bare root and container grown stock - three treatments and at two seasons - Fall 1975 and Spring 1976. Averages from 4 replications at each location. Data shows per cent survival 2 months after planting and 5 months after final planting.

Species	Treatments*	Drill Hole G-3		Drill Hole G-17		Section 6		Average of 3 Locations	
		June %	Oct %	June %	Oct %	June %	Oct %	June %	Oct %
Beardless bluebunch grass	F BR A	100	75	100	25	100	0	100	33
	F BR B	50	50	75	50	100	25	75	42
	F BR C	75	50	25	0	75	25	58	25
	S BR A	50	50	100	75	100	50	83	58
	S BR B	75	50	75	75	100	50	83	58
	S BR C	100	75	50	50	100	50	83	58
	F CO A	100	100	100	100	75	50	92	83
	F CO B	75	75	75	50	100	75	83	67
	F CO C	75	75	75	75	100	50	83	67
	S CO A	100	100	100	100	75	50	92	83
	S CO B	100	75	75	50	100	25	92	50
	S CO C	100	100	75	50	100	25	92	58

Treatments* and Seasons

F = Fall
S = Spring

BR = Bare root transplanting stock
CO = Container grown transplanting stock

A = Control
B = Water at time of planting
C - Water and fertilizer at time of planting

Table 27. Percent survival of 5 grass species using 2 methods of planting at 2 seasons and at 3 locations. Data is the average of 3 treatments and 4 replications. Observations were made in the fall of 1976.

		Location			
Species	Method and Season of Planting*	Drill Hole G-3	Drill Hole G-17	Sec. 6	Ave.
		%	%	%	%
Indian rice grass	F BR	25	42	0	22
	S BR	83	92	33	69
	F CO	75	75	25	58
	S CO	83	25	17	42
Needle & thread grass	F BR	42	33	0	25
	S BR	67	75	17	53
	F CO	58	75	8	47
	S CO	100	92	33	75
Fairway crested wheat grass	F BR	75	42	25	47
	S BR	100	75	100	92
	F CO	67	83	92	81
	S CO	83	83	50	72
Western wheat grass	F BR	75	58	67	67
	S BR	67	50	100	72
	F CO	100	92	92	95
	S CO	83	92	67	81
Beardless bluebunch wheat grass	F BR	58	25	17	33
	S BR	58	67	50	58
	F CO	83	75	58	72
	S CO	92	67	33	64

*Season of planting:

F = Fall Planting date: October 29-31, 1975
S = Spring Planting date: April 1-7, 1976

Method of planting:

BR = bare root planting stock
CO = container grown planting stock

of fourwing saltbush, but these are not attributed to pruning (Table 28). Survival success from this bare-root planting has been extremely high. Rodents have been a problem, but the plot area was free from weed competition. Pruning had no measurable influence on vegetative growth (Table 29). Differences in growth are attributed to variabilities between plants and not due to treatments. The Bridger form of fourwing saltbush was highly palatable to rodents as the plants were grazed to short stems and a few died. Limited grazing by rodents generally occurred to the other forms of fourwing saltbush. Rodent grazing on winterfat was variable and some plants were grazed heavily which may have caused some plant losses. Siberian salt tree, a legume, was not grazed.

D. Anti-Desiccant Chemicals to Aid in Survival of Bare-Root Transplants.

The use of anti-desiccants for diminishing moisture losses through transpiration had no conclusive effect on survival (Table 30).

E. Survival of Shrub, Forb and Grass Transplants in 2-Meter-Square Boxes Filled with Paraho Processed Shale.

The survival of container-grown shrub transplants was good when the soil material surrounding the container-grown plant consisted of a volume measuring two inches square by six inches in depth. Table 31 summarizes the results of two replications containing Colorado shale that had weathered and received moisture in the boxes over winter. The other two replications contained Utah Paraho processed shale that was dust dry and placed in the boxes just prior to planting in mid-April. Limited water was added by a sprinkler can at the time of planting. The variability in plant survival between the two shales and in handling as mentioned above is shown in Table 32. Only a fourwing saltbush and a winterfat plant under high stress and little growth was surviving in the straight

Table 28. Effect of pruning on establishment and survival of bare root shrub transplants. Per cent live plants from 6 replications at 2 observation dates - June 1976 and October 1976.

Species	Treatments[1] 1		2		3		4		5		6		7		8		Average	
	June %	Oct %	June %	Oct %	June %	Oct %	June %	Oct %	June %	Oct %	June %	Oct %	June %	Oct %	June %	Oct %	June %	Oct %
Siberian salttree	100	83	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	98
Fourwing saltbush - UB2	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Fourwing saltbush - UB3A	100	100	83	83	100	100	100	100	100	100	100	100	100	100	100	83	100	96
Fourwing saltbush - Bridger	100	100	100	83	83	50	100	50	100	67	83	67	100	83	100	83	96	73
Fourwing saltbush - Kane Valley	100	83	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	98
Winterfat	100	33	100	67	67	67	83	17	100	100	67	33	67	33	67	50	81	50

Treatments[1]

	Top	Root	
1.	Unpruned	Unpruned	Control
2.	Unpruned	Unpruned	Watered (1 l. at time of planting)
3.	Pruned	Unpruned	Control
4.	Pruned	Unpruned	Watered (1 l. at time of planting)
5.	Unpruned	Pruned	Control
6.	Unpruned	Pruned	Watered (1 l. at time of planting)
7.	Pruned	Pruned	Control
8.	Pruned	Pruned	Watered (1 l. at time of planting)

The roots were pruned by undercutting in the fall of 1975 and lifted April 20, 1976. The vegetative top growth was pruned April 21, 1976.

Table 29. Effect of pruning on growth of bare root shrub transplants. Data shows average from 6 replications for height, width and growth index (average of height plus width) for 8 treatments.

		Species[1]					
Treatments[2]		Salt Tree	Atca UB2	Atca UB3A	Atca Bridger	Atca Kane Valley	Winterfat
1	Height	15	19	27	2	27	5
	Width	6	37	39	6	29	5
	Index[3]	10.5	28	33	4	28	5
2	Height	14	17	24	1	23	5
	Width	8	39	45	5	31	4
	Index	11	28	34.5	3	27	4.5
3	Height	9	17	25	1	20	3
	Width	10	36	41	5	27	5
	Index	9.5	26.5	33	3	23.5	4
4	Height	7	17	25	2	20	10
	Width	11	31	49	3	24	7
	Index	9	24	37	2.5	22	8.5
5	Height	12	25	18	2	27	5
	Width	10	47	40	12	32	5
	Index	11	36	29	7	29.5	5
6	Height	11	17	24	3	26	3
	Width	10	26	46	5	34	6
	Index	10.5	21.5	35	4	30	4.5
7	Height	11	17	21	1	23	6
	Width	9	37	41	4	26	5
	Index	10	27	31	2.5	24.5	5.5
8	Height	11	15	25	1	21	2
	Width	8	37	44	5	36	5
	Index	9.5	26	34.5	3	28.5	3.5
Total Ave.	Height	11	18	24	2	23	5
	Width	9	36	43	6	30	5
	Index	10	27	33.5	4	26.5	5

---

[1] Species	Source
Siberian salt tree	Russia
Atca UB2, Fourwing saltbush	Oil shale tract
Atca UB3A, Fourwing saltbush	Oil shale tract
Atca Bridger, Fourwing saltbush	Bridger, Montana
Atca Kane Valley, Fourwing saltbush	Sanpete County, Utah
Winterfat	Oil shale tract

Table 29 (continued)
Effect of pruning on growth of bare root shrub transplants.
Data shows average from 6 replications for height, width and growth index (average of height plus width) for 8 treatments.

---

[2] Treatments

	Top	Root	
1.	Unpruned	Unpruned	Control
2.	Unpruned	Unpruned	Watered (1 l. at time of planting)
3.	Pruned	Unpruned	Control
4.	Pruned	Unpruned	Watered (1 l. at time of planting)
5.	Unpruned	Pruned	Control
6.	Unpruned	Pruned	Watered (1 l. at time of planting)
7.	Pruned	Pruned	Control
8.	Pruned	Pruned	Watered (1 l. at time of planting)

The roots were pruned by undercutting in the fall of 1975 and lifted April 20, 1976. The vegetative top growth was pruned April 21, 1976.

[3] Index = average of height plus width

No measurable difference in survival or growth. Bridger ecotype of Fourwing saltbush was severely damaged by rodents. Slight nibbling on the other Fourwing saltbushes. Winterfat did poorly.

Table 30. Effect of anti-desiccant chemicals on per cent survival of bare rooted transplants when field planted from observations made in June 1976 and October 1976. Data are the average of four replications.

Species	Treatments[1] 1		2		3		4	
	June %	Oct %	June %	Oct %	June %	Oct %	June %	Oct %
Winterfat	25	50	25	0	50	25	75	0
Big sagebrush	100	75	50	25	100	100	50	25
Shadscale saltbush	50	25	100	75	75	50	100	50
Siberian salt tree	100	100	100	100	100	100	100	100
Fourwing saltbush	50	100	100	100	100	100	100	100
Average	65	70	75	60	85	75	85	55

Treatments[1]

1. Control
2. Dig plant & spray with Wilt Proof
3. Dig plant & dip in solution of Weather Shield XX 1 to 1 concentration
4. Dig plant and dip in a 1 to 10 solution of Wilt Proof formula NCF

Date of planting and treatments - April 22, 1976

Table 31. Effect of Paraho Processed Shale on performance of container grown shrubs. Summary of 4 replications[1] showing per cent survival at 2 dates following field planting.

Species	Treatments[2] Shale Total Live Plants		Soil Over Shale Total Live Plants	
	June %	Sept %	June %	Sept %
Fourwing saltbush	92	42	100	100
Cuneate saltbush	92	42	100	83
Shadscale	92	50	100	100
Greasewood	75	25	100	75
Black sagebrush	83	0	92	0
Douglas rabbitbrush	50	0	92	0
Winterfat	83	42	100	83
Big sagebrush	75	0	83	41

[1] There were three plants per replication in each growth material or a total of 12 in shale and 12 in soil over shale.

[2] Shale consists of 30 cm. of paraho processed shale. Soil over shale consists of 15 cm. of paraho processed shale overlaid with 15 cm. of local soil.

Plant date - April 8 thru April 27, 1976
Observation dates for survival - June 10, 1976
September 30, 1976

Table 32. Effect of paraho processed shale on performance of container grown shrubs when shrubs are planted in complete shale versus shale covered by soil.[1] Summary of 2 replications[2] showing per cent survival and plant growth.[3]

	Shale				Soil Over Shale			
Species	Utah Live	Utah Growth	Colo Live	Colo Growth	Utah Live	Utah Growth	Colo Live	Colo Growth
	%	cm	%	cm	%	cm	%	cm
Fourwing saltbush	17	3	67	29	100	26	100	18
Cuneate saltbush	0	-	83	11	83	9	83	9
Shadscale	0	-	100	7	100	6	100	8
Greasewood	0	-	50	10	50	11	100	11
Black sagebrush	0	-	0	-	0	-	0	-
Douglas rabbitbrush	0	-	0	-	0	-	0	-
Winterfat	17	2	67	3	67	4	100	5
Big sagebrush	0	-	0	-	50	2	33	5

[1] There were 3 plants per replication in each growth material or a total of 12 in shale and 12 in soil over shale.

[2] Two replications contain processed shale from Utah and 2 from Colorado making a total of 4 replications. There were 3 plants of each species per replication in each growth material or a total of 12 in shale (6 Utah and 6 Colorado) and 12 in soil over shale.

[3] Plant growth is the average of height plus width.

Planting date: April 8 thru April 27, 1976.
Observation date for survival and plant growth: September 30, 1976.

Utah processed shale, while five species with fair growth were alive in the Colorado shale which had weathered and collected natural moisture over the winter. Both types of shale when covered with soil had a fair to excellent plant survival with the exception of black sagebrush and Douglas rabbitbrush. In a set of smaller boxes containing Colorado processed shale and soil over shale, all the grasses and forbs survived from a limited to 100 percent in the soil over the shale (Table 33). Seepweed (*Suaeda nigra*), prostrate summer cypress (*Kochia prostrata*) and western wheatgrass had the best survival when planted as container-grown stock in 15 cm of paraho processed shale covered with 15 cm of soil. The forbs, seepweed and summer cypress, both did well in the straight shale. The only grasses surviving in the fall following spring planting were Inland saltgrass and sand dropseed.

F. Field Observation Nursery at Section 6 Research Site

In general there has been poor to fair survival of those species planted (Table 34). Only cuneate saltbush from Wildcat Mesa, Garfield County, had an 100 percent survival. This nursery will be enlarged with additional species and ecotypes of species included.

Table 33. Effect of Paraho Processed Shale on performance of container grown grass and forb species. Summary of 4 replications[1] showing per cent of live plants at two observation dates.

Species	Treatments[2] Shale Total Live Plants		Soil Over Shale Total Live Plants	
	June %	Sept %	June %	Sept %
Indian ricegrass	94	0	100	25
Sand dropseed (Reps 1 & 2)	87	12	100	12
Russian wildrye grass (Reps 3 & 4)	100	0	100	37
Western wheatgrass	81	0	100	69
Needle and thread grass	94	0	94	6
Saltgrass	100	19	100	44
Seepweed	81	62	100	100
Prostrate summer cypress	87	44	100	87

[1] There were 4 plants per replication in each growth material or a total of 16.

[2] Shale consists of 30 cm. of paraho processed shale. Soil over shale consists of 15 cm. of paraho processed shale overlaid with 15 cm. of local soil.

Planting date - April 9 thru April 27, 1976
Plant survival observations - June 10, 1976
September 30, 1976

Table 34. Field nursery and observation garden planted in Section 6 research site. Present species planted in April 1976. Data presents per cent of live plants, September 30, 1976.

Row	Species	Source	Live Plants %
1.	*Erigonum corymbosum*	East Duchesne, Hway 40, Duchesne Co.	0
2.	*Erigonum spp.*	Indian Canyon, South Duchesne, State 133, Duchesne Co.	20
3.	*Tamarix pentandra*	White River Bridge, Bonanza, Uintah Co.	40
4.	*Halimodendron halodendron*	Russia	20
5.	*Agropyron spp.*	Southam Canyon, Oil Shale Tract Ua, Uintah Co.	80
6.	*Gutierrezia sarothrae*	Oil Shale Tract Ub, Uintah Co.	80
7.	*Artemisia pygmaea*	West Duchesne, Hway 40, Duchesne Co.	0
8.	*Phlox caespitosa*	Drill Hole G-3, Oil Shale Tract Ua, Uintah Co.	0
9.	*Oryzopsis hymenoides* (dwarf form)	Northeast Vernal, Uintah Co.	80
10.	*Agropyron elongatum*	Commercial	60
11.	*Elymus junceus*	Commercial	80
12.	*Atriplex cuneata*	USU #325 Wildcat Mesa, Garfield Co.	100

Table 34 (continued)
Field nursery and observation garden planted in Section 6 research site. Present species planted in April 1976. Data presents per cent of live plants, September 30, 1976.

Row	Species	Source	Live Plants %
13.	*Kochia prostrata*	Russia	80
14.	*Atriplex corrugata*	USU #326 Wildcat Mesa, Garfield Co.	80
15.	*Artemisia spinescens*	East Bonanza, Uintah Co.	0
16.	*Agropyron inerme*	Watson, Uintah Co.	60
17.	*Juniperus osteosperma*	Oil shale tract Ua, Uintah Co.	0

IX. LEACHING OF COLUMNS OF PARAHO PROCESSED SHALE

A. Introduction

One of the frequently discussed problems relating to the proposed plan to dispose of processed shale is the depth of percolation and fate of natural precipitation in a shale disposal pile. Other questions relate to this general problem, such as the possibility of leaching surface salts to great depths, possible salt accomulation in toxic quantities, and the amount of water necessary to leach salts out of the coarse Paraho processed shale to the point that plants of varying tolerance to salt would be able to grow on the shale.

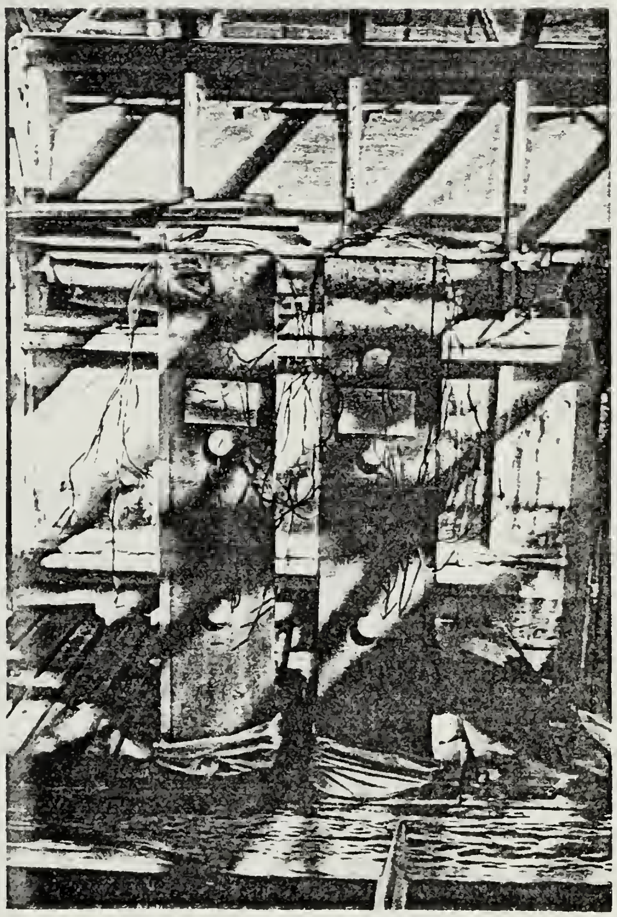
B. Methods

To answer some of these problems, a series of columns of Colorado Paraho processed shale 90 cm (3 feet) deep and 20 cm x 20 cm (8 inches x 8 inches) square were established in the greenhouse for leaching with various amounts of water. Three treatments were applied in four replications: (1) water to leach to 30 cm depth, (2) water to leach to 60 cm depth and (3) water to leach completely through the column plus successive amounts.

Columns were instrumented with soil moisture psychrometers to detect when leaching had proceeded to the desired depth (Figure 6). Samples were removed for moisture verification using a psychrometer micro-sample changer.

Each .5 liter of leachate passing through the columns was tested for electrical conductivity. Samples were then submitted to the laboratory for individual cation analysis.

FIGURE 6. Columns of Paraho processed shale instrumented for moisture detection at three depths in a leaching study. Columns are 20 x 90 cm.



Columns where leaching occurred only to the 30 cm or 60 cm depth were dismantled at the end of the study and shale was sampled in and above the leached zone for electrical conductivity. Results from these samples are not yet available.

C. Results

At the time of preparing this report, only data from the fully leached columns are available for presentation. The first half-liter increment of leachate passing through the columns was very saline and measured 35 mmhos/cm EC (Figure 7). By the time four liters had passed through the columns, the EC had reduced to 8 mmhos/cm. The degree of salinity leveled off as six liters passed through the columns. It does not appear that a complete leaching of salts can occur within a reasonable amount of leaching as shown by the leaching curve which still shows an EC of 2.5 mmhos/cm 15 liters of leaching.

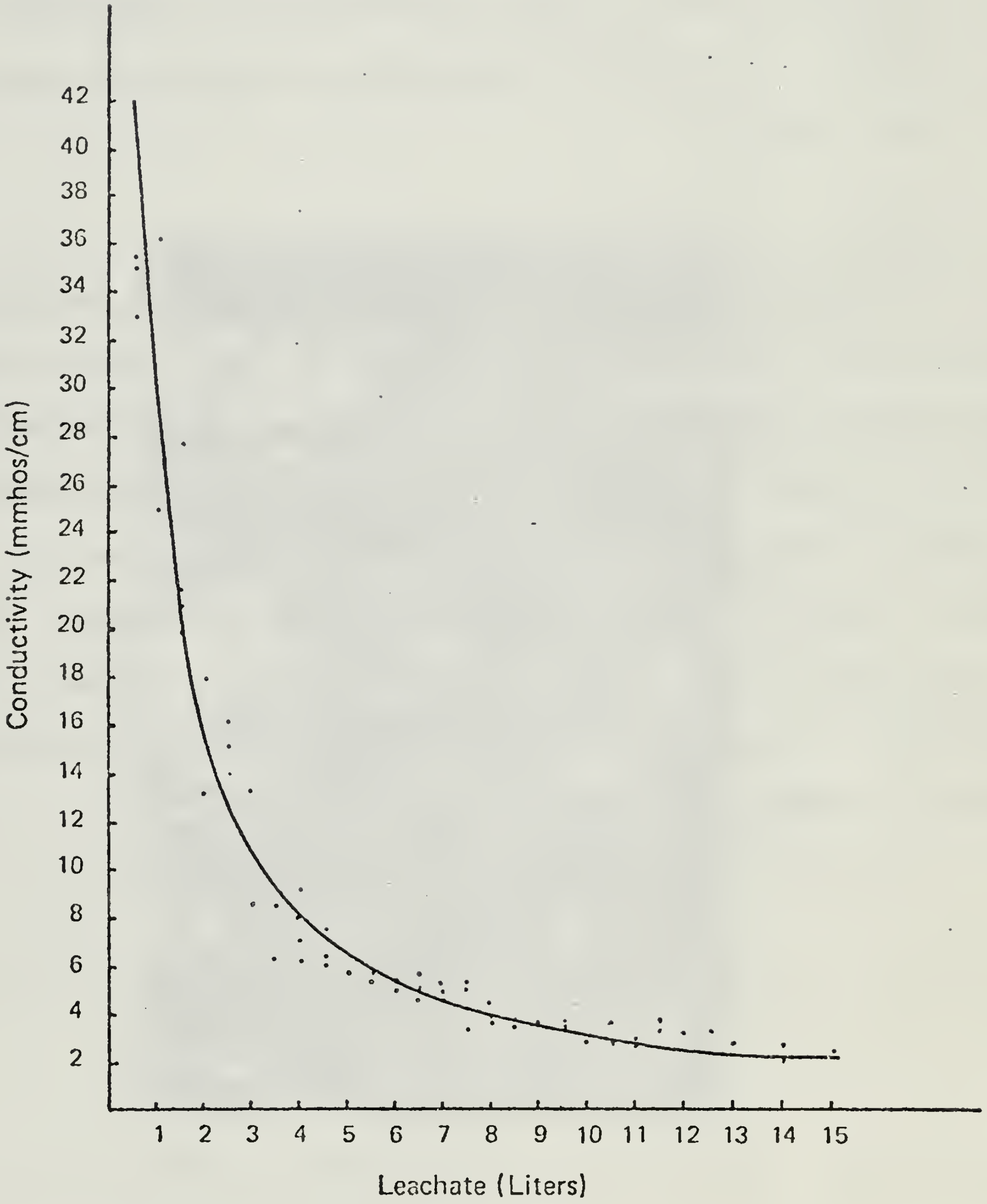


FIGURE 7. Conductivity of ½ liter leachate increments from a 90 cm column of Paraho processed shale

X. WATER HARVESTING STUDIES

The concept of water harvesting and application of results have been described in previous reports. In 1976 we were able to test two sizes of water harvesting basins that had been treated in July to stabilize and seal the surface. Also tested was the effectiveness of soil stabilization compound number 3011, a polyvinyl acetate produced by Union Oil Company, and Aerospray 70, a compound marketed by American Cyanimid Company.

A. Methods

Two studies were laid out in late 1975. The first study employed 20 basins 20 cm deep (8 inches) and 1.5 m (5 feet) in diameter. The second employed 20 basins 10 cm deep (4 inches) and .75 m (2.5 feet) in diameter. In the center of each basin a one-gallon can was installed to measure water. A 20-cm-square patch of 6 mil polyethylene sheet plastic was used to cover the lip of the can to prevent water running down the side of the can instead of draining into it. A light covering of soil was placed over the plastic before the soil sealant was applied. Subsequently, a small drain hole was made in the plastic to allow water drainage into the can.

To the 20 small basins, the following rates of polyvinyl acetate compound were applied:

Treatment	Water Dilution	Rate
1	1:6	check
2	1:6	200 gals/acre concentrate
3	1:6	400 gals/acre concentrate
4	1:6	100 gals + 100 gals concentrate reapplied
5	1:6	200 gals + 200 gals concentrate reapplied

To the 20 large basins, the following treatments were applied:

Treat Treatment	Water Dilution	Rate
1	1:6	check
2	1:6	50 gals/acre of compound
3	1:6	100 gals/acre of compound
4	1:6	25 gals/acre + 25 gals compound reapplied
5	1:6	50 gals/acre + 50 gals compound reapplied

The material was applied with a hand pump pressure sprayer on a warm day to dry soil. Curing of the compound occurred rapidly with no difficulty observed.

B. Results

Harvest of water from the first rainfall which occurred in mid-September was measured on September 23, 1976 (Figure 8). The results from the large basins were eratic and inconclusive (Table 35). The small basins provided more uniform data but were still highly variable in relation to treatments (Table 36). There was a trend in both size basins for increased water collection with a surface treatment. The best treatment was the high rate of product 3011, either as a single application or a split application.

A problem with decomposition of the plastic cover also added to the variability because breaks and holes occurred in the plastic of some cans, thus allowing differential evaporation. An inspection of the degree of plastic decomposition appeared to correlate with the low measurement from some cans.

A further test of water harvesting was run on September 24 employing artificial application of precipitation from a sprinkler can. The amount of water applied was calculated to be equal to a .5 cm (.2 inch) rainfall.

FIGURE 8. Measurement of water collected in a container in the bottom of a small basin treated with a polyvinyl acetate surface stabilizer.

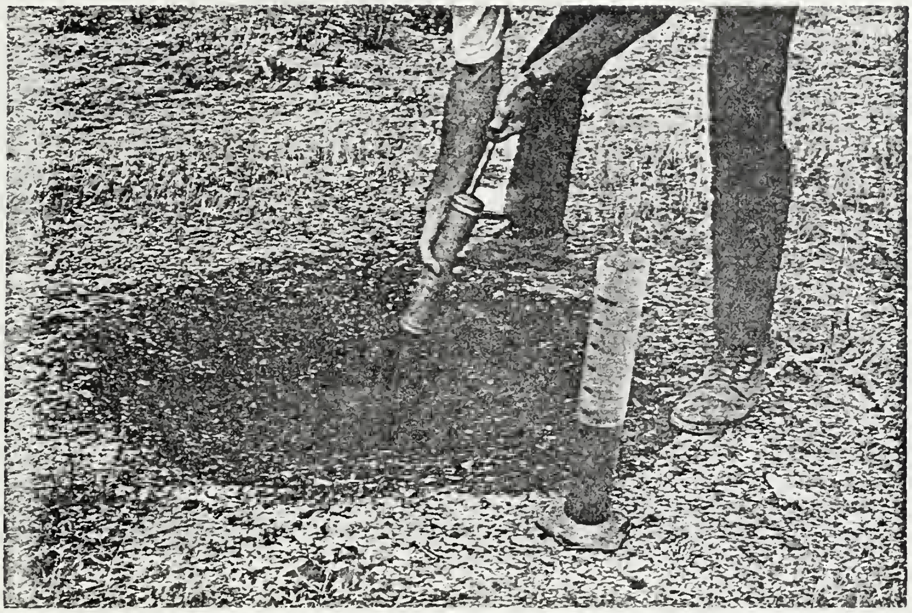


Table 35. Amount of water collected in cans in the bottom of 8-inch deep (20 cm) 5-foot diameter (1.5 m) basins treated variously with a polyvinyl acetate stabilizing compound. Measurements were made on September 23, 1976, one week after a .17-inch rainfall.

	Treatment				
Replication	1	2	3	4	5
I	480	1990	2290	340	2050
II	2060	1160	1200	2130	1580
III	2010	540	1310	930	50
IV	0	0	820	350	2030
Total	4550	3690	5620	3730	5710
Average	1137	922	1405	932	1427

Table 36. Amount of water collected in cans in the bottom of 4-inch (10 cm) deep, 2.5-foot diameter (.75 m) basins treated variously with a polyvinyl acetate stabilizing compound. Measurements were made on September 23, 1976, one week after a .17 inch rainfall.

	Treatment				
Replication	1	2	3	4	5
I	1150	0	1340	420	2320
II	120	1610	2060	50	2600
III	1510	1580	1930	150	1320
IV	140	140	2420	2300	2320
Total	2920	3330	7750	2920	8560
Average	730	832	1937	730	2140

Results from the artificial application are shown in Table 37. Again, considerable variation among the replicates of individual treatments occurred. Check basins also collected a considerable amount of water in relation to the surface-treated plots. Large basins appeared to be less effective in harvesting water into the collector cans in the bottom. This is probably because they had a more flattened bottom than the small basins and some water percolated into the soil rather than surface draining into the collection can.

The treated small basins appeared to be good collectors of surface runoff. The 400 lbs/acre rates of compound 3011 was twice as effective as the 200 lbs/acre rate applied in a single or a split rate.

C. Planned Work for 1977

Further tests will be run in the spring in relation to natural precipitation. All of the plastic extending over the top of the collector cans has been removed to within 1.3 cm (.5 inch) of the rim of the can and in its place as an evaporation retardant has been added 30 ml of motor oil.

After the spring precipitation measurements have been made, all of the gallon cans will be removed and shrub transplants will be placed in the bottom of the basins.

An evaluation of the surface sealing material will be made in the late spring of 1977 to assess durability, strength and resistance to weathering.

Table 37. Water harvesting from a simulated rainfall of .5 cm (.20 inch) applied with a sprinkler can to basins of two sizes; 20 cm (8 inches) deep and 1.5 m in diameter (5 feet) and 10 cm (4 inches) deep and .75 m in diameter (2.5 feet).

	Treatments				
Replication	1	2	3	4	5
Large Basins					
I	1000	330	850	110	1100
II	840	180	110	1140	240
III	1000	445	240	830	0
IV	300	0	1170	440	410
Total	3140	955	2370	2520	1750
Average	785	239	595	630	437
Small Basins					
I	245	530	1560	1230	1260
II	430	720	1100	250	1010
III	200	750	1470	220	1150
IV	800	70	1290	750	1580
Total	1675	2070	5420	2450	5000
Average	419	518	1355	612	1250

XI. PILOT MODEL OF AN OIL SHALE DISPOSAL PILE

During the summer we constructed a small 4-section pilot model of a disposal pile that consisted of a 2-meter 4:1 slope and a one-meter flat terrace. In the terrace area was installed a 45 cm x 60 cm trench filled with topsoil (Figure 9 and 10). The pilot model is 120 cm (4 feet) deep at the front and 90 cm (3 feet) deep in the rear. Side walls are made of 2 x 8 rough sawn lumber with 2-cm thick plywood dividers between treatments. A cement floor was poured in the pilot model and each section was sloped into a drain to which a polyethylene pipe was connected and extended to a collection container at the front of the model.

Processed shale was loaded into the model and compacted with a hand tamp. During the loading process moisture and salinity sensors were installed in the shale and in the topsoil trench at 45 cm (18 inches) and 75 cm (30 inches) depth (Figure 9).

The two types of processed Utah shale were placed in the model: Paraho and Union Oil Company. One-half of the slope surface of each processed shale type was treated with a soil surface stabilizer, Union Oil Company product 3011, a polyvinyl acetate:

Section A Utah shale paraho process
B Utah shale paraho process plus surface stabilizer
C Utah shale, Union Oil Company process
D Utah shale Union Oil Company process plus surface stabilizer.

Treatments

A Paraho Process
B Paraho Process Surface Stabilized
C Union Process
D Union Process Surface Stabilized

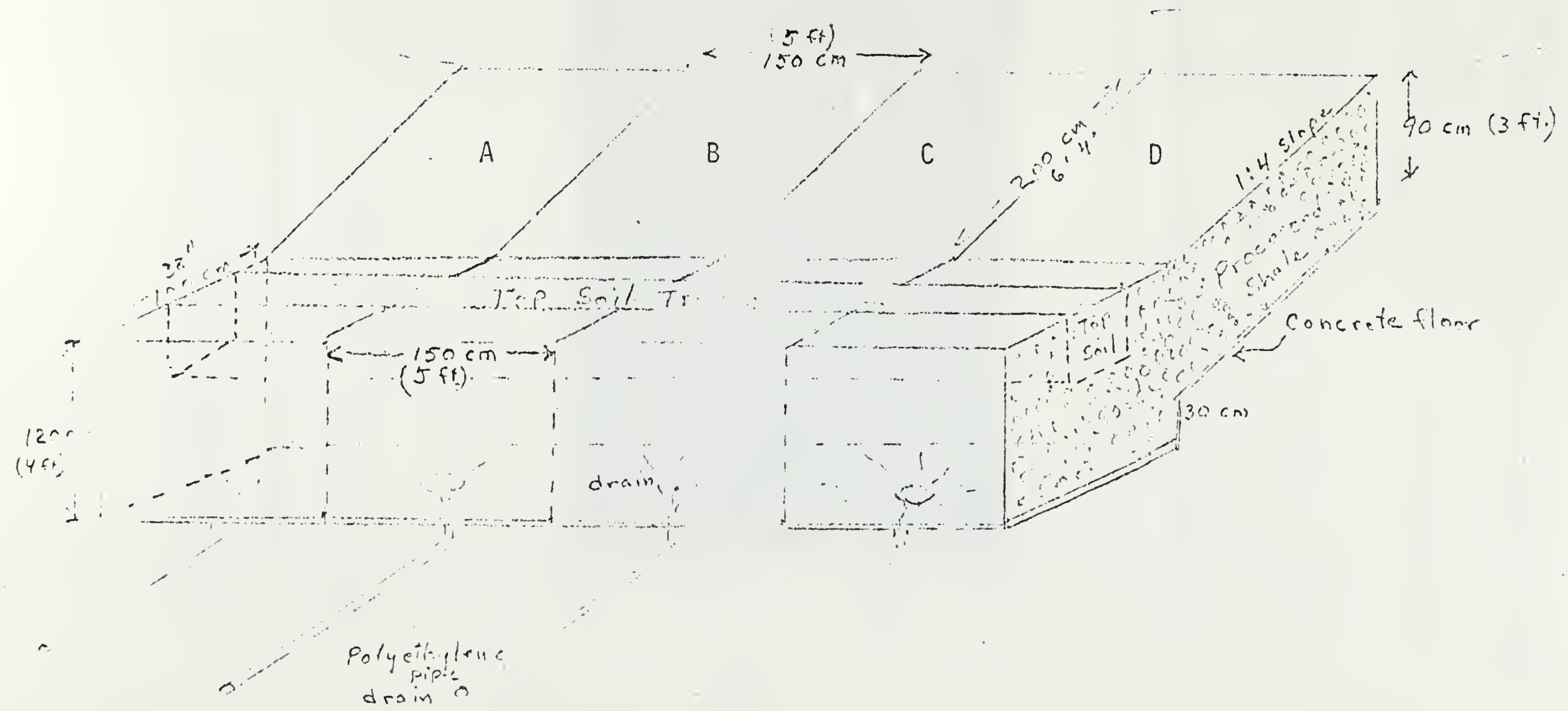
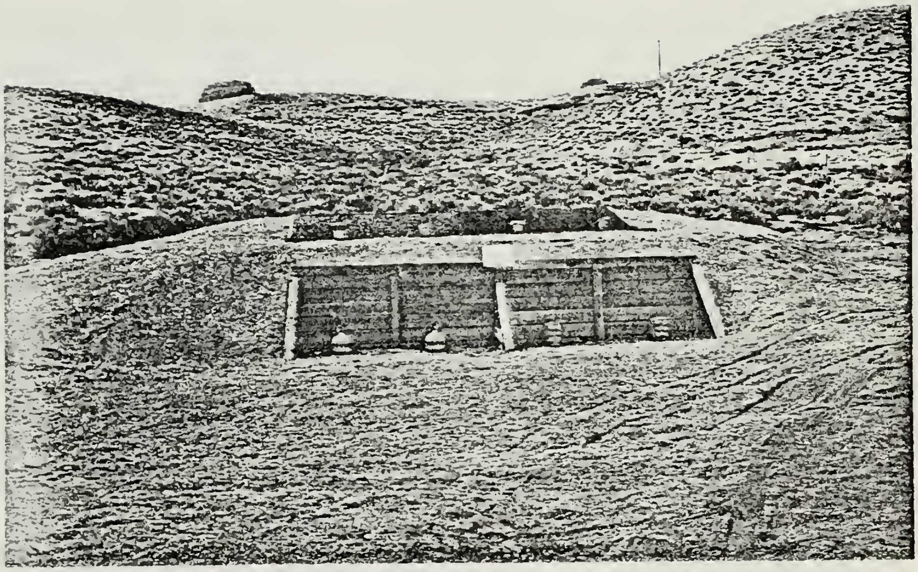


Fig. 9. Schematic View of Pilot Model of Processed Oil Shale Disposal Pile.

FIGURE 10. Views of pilot model during and after installation.



The area around the pilot model was banked up with topsoil to the level of the model and a drainage channel was dug to avoid flooding from surface runoff up the slope from the model.

A. Future Plans for the Pilot Model Study

At the present time we do not plan to add supplemental water and will wait for percolation of regular precipitation through the pile and subsequent collection at the bottom of the pile into the drain system.

We wish to observe moisture and salinity relationships and test whether a surface sealant may provide greater water harvest into the topsoil trench there to be measured by moisture and salinity sensors.

In the early spring we will plant container-grown plants in the topsoil trench of each section and obtain growth measurements in subsequent months.

In summer, the data to be obtained from this study is expected to include the following:

1. Leachate quantity
2. Leachate chemical and salinity concentrations
3. Soil moisture potential within the pile at various locations
4. Salinity measurements within the pile at various locations
5. Plant growth (height) in a topsoil trench in two types of processed shale with and without surface stabilizer on the slopes.

XII. PLANNED RESEARCH FOR 1977

A. Continuation of existing studies will consume the greatest portion of time of the research group.. Some of the studies will be summarized in 1977 for publication either as Institute for Land Rehabilitation numbered series reports or as papers in regular journals.

B. New studies with water and salinity functions in deposits of processed oil shale will be established. We expect to do a study on a combined assessment of revegetation in relation to microbiological functions, leaching of salts and movement of water in processed oil shale.

C. Several new physiological studies will be initiated on native shrub tolerance to levels of individual salts found in processed shale and the various ammendments or practices that may be used to ameliorate high levels of toxic elements.

D. Propagation methods for obtaining planting materials of native plants will be further studied in 1977. Our objective is to produce a handbook of methods and appropriate practices for the most promising plants in the oil shale region.

E. We will continue to prepare research proposals and present them to appropriate agencies for funding. Thus, our research effort on oil shale will be expanded and extended.

XIII. RESEARCH PROPOSALS PREPARED

During the period July 1, 1976 to December 31, 1976, a research proposal "A Pilot Model

was prepared and submitted to ERDA. This proposal was received and is presently in the process of review and rewriting.

We have two to four proposal concepts in the early stages of development and will be doing further work on them in the next six months.

XIV. PUBLICATION PLANS

At the present time we are preparing drafts of manuscripts for publication that will present findings relevant to land rehabilitation associated with oil shale development. Some tentative titles include:

A. A bibliography of research on the germination and establishment of woody *Atriplex*.

B. Germination and establishment of cheatgrass and Russian thistle on Paraho processed shale.

C. Rehabilitation plantings on disturbed arid sites.

D. Leaching of salts in columns of Paraho processed shale.

E. Two M.S. theses will be prepared and presented for defense within the next six months.

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(June 1984)

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